Project South Salmon Farm Development: Marine Pest Assessment of Effects

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Prepared by

Barrie Forrest

for

Sanford Limited

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barrie@saltecology.co.nz, +64 (0)27 627 4631

www.saltecology.co.nz

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BACKGROUND

Sanford Ltd propose a salmon farm development south east of Ruapuke Island and east of Foveaux Strait (Project South). Among the ecological and broader environmental effects associated with such a development are potential marine biosecurity issues. Marine biosecurity in New Zealand refers to the management of risks posed by organisms that are potentially harmful to environmental, economic, social and cultural values. Aquaculture is in the relatively unique situation of being a potential exacerbator of biosecurity risk, while also being vulnerable to adverse effects from harmful organisms. This report provides an assessment of marine pest risks associated with the proposal, with disease aspects of marine biosecurity considered in a separate assessment.

ASSESSMENT OF MARINE PEST EFFECTS

Aquaculture in New Zealand is highly unlikely to contribute to marine pest risk at the border but, once pests become established, aquaculture activities can become an exacerbator of risk in the following main ways:

- Risk pathways (e.g. vessel or equipment movements) associated with aquaculture activities can lead to the inadvertent spread of marine pests, especially as 'hitch hikers' within hull biofouling.
- Marine farms provide habitats on which certain species may become prolific. As well as potentially impacting on-farm operations, the farms may act as a reservoir for further marine pest spread into the wider environment (e.g. by natural dispersal, or through infection of vessels and other transport vectors).
- Farm wastes may create environmental conditions (e.g. seabed enrichment) that locally facilitate the establishment or proliferation of certain marine pests.

The assessment of effects for the Project South proposal requires an understanding of how salmon farm development and operations may alter the existing biosecurity risk profile of the region. Southland is already at risk from the introduction and spread of marine pests due primarily to inter-regional and international vessel movements, which connect Southland to source ports and harbours where recognised and potential pest species are established. One of the most likely risk mechanisms associated with these vessel movements is pest transfer via hull biofouling. Seven species are listed as marine pests in the Southland Regional Pest Management Plan (SRPMP). Of these, six are not thought to be established in the Southland region, but occur in certain locations elsewhere in New Zealand. The SRPMP aims to prevent the introduction of these species. The remaining species is the Asian kelp *Undaria pinnatifida*, which is already established and subject to an objective and associated rules in the SRPMP to progressively contain and reduce its geographic distribution, and prevent further *Undaria* infestations.

In the context of this background, Table 3 of the main report summarises the incremental marine pest risk from the project proposal. Of the processes outlined above, the most important is the movement of vessels and equipment associated with proposed salmon farming activities. Of particular importance are vessels or equipment that may arrive from external source regions that contain designated pests (including some of the SRPMP pests) and other potentially harmful species that have not been previously recorded in Southland. Although the risk of introducing new pests to the region exists already, the proposed development has the potential to introduce such 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 to an extent where the level of residual risk is acceptable.

Furthermore, the other main processes described above are expected to be of minor significance in the context of this project. The role of farms 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 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, temperature ranges at the lower end of known tolerance for some species, and relatively featureless soft-sediment habitats in the farming environs.

MANAGEMENT

It is recommended that effective measures for managing known marine pest risks, and addressing uncertainties, are incorporated into a biosecurity management plan (BMP), which should complement simultaneous measures developed for disease risk management. The details of a BMP can be developed if the application is successful and once operational details are finalised; however, some key BMP objectives and recommended management approaches are outlined in the main report. They include the following:

- Effective management of risk pathways to minimise the likelihood of introduction to the farming areas of potentially harmful organisms. As well as excluding target pests, the measures proposed are generic to biofouling, water and sediment. For example, they include hull biofouling approaches that would minimise the risk of all potentially harmful organisms being spread by biofouling, irrespective of their designated status as pests.
- On-farm measures, including passive surveillance to detect potentially harmful organisms, and implementation of measures to eliminate or contain new incursions or achieve ongoing control. The focus should be on practical operational measures that could be put in place to reduce on-farm risk.

Some broader considerations are also raised in the main report, including implementing a staged development approach to deal with uncertainty and help safeguard against the potential for significant unforeseeable events.

Furthermore, it is recognised that the final agreed BMP measures need to be effective (i.e. have a high likelihood of achieving BMP objectives) and therefore worthwhile. The latter requires that BMP efficacy is not undermined by existing sources of unmanaged risk. In that eventuality, management may be largely futile and place an unnecessary burden on Sanford, its contractors and Environment Southland.

1. INTRODUCTION

Sanford Ltd propose a 'Project South' salmon farm development east of Foveaux Strait, and to the south east of Ruapuke Island (Fig. 1). Among the ecological and broader environmental effects associated with such a development are potential marine biosecurity issues. Marine biosecurity in New Zealand refers to the management of risks posed by organisms that are potentially harmful to environmental, economic, social and cultural values. Aquaculture is in the relatively unique situation of being a potential exacerbator of biosecurity risk, while also being vulnerable to adverse effects from harmful organisms. In the context of the project proposal the two main biosecurity aspects to consider are:

- The spread and potential effects of marine pests, including (but not limited to) marine seaweed and invertebrate species designated as pests by Environment Southland (SRPMP 2019) and the Ministry for Primary Industries (MPI 2015).
- The interactions between salmon aquaculture and the wider environment with respect to the introduction, spread or emergence of disease agents (pathogens and parasites).

Salt Ecology was contracted by Sanford to provide the assessment of marine pest risks associated with the proposal, with the disease component addressed in a separate veterinary assessment.

The present report undertakes the following:

- Provides an overview of marine biosecurity in New Zealand and the contribution of aquaculture to the spread of marine pests.
- Describes the current profile of the Southland region in terms of the high-risk species already present, the existing activities that contribute to regional risk, and values potentially at-risk.
- Describes the proposal-specific activities and the incremental marine biosecurity risk they present with respect to marine pests.

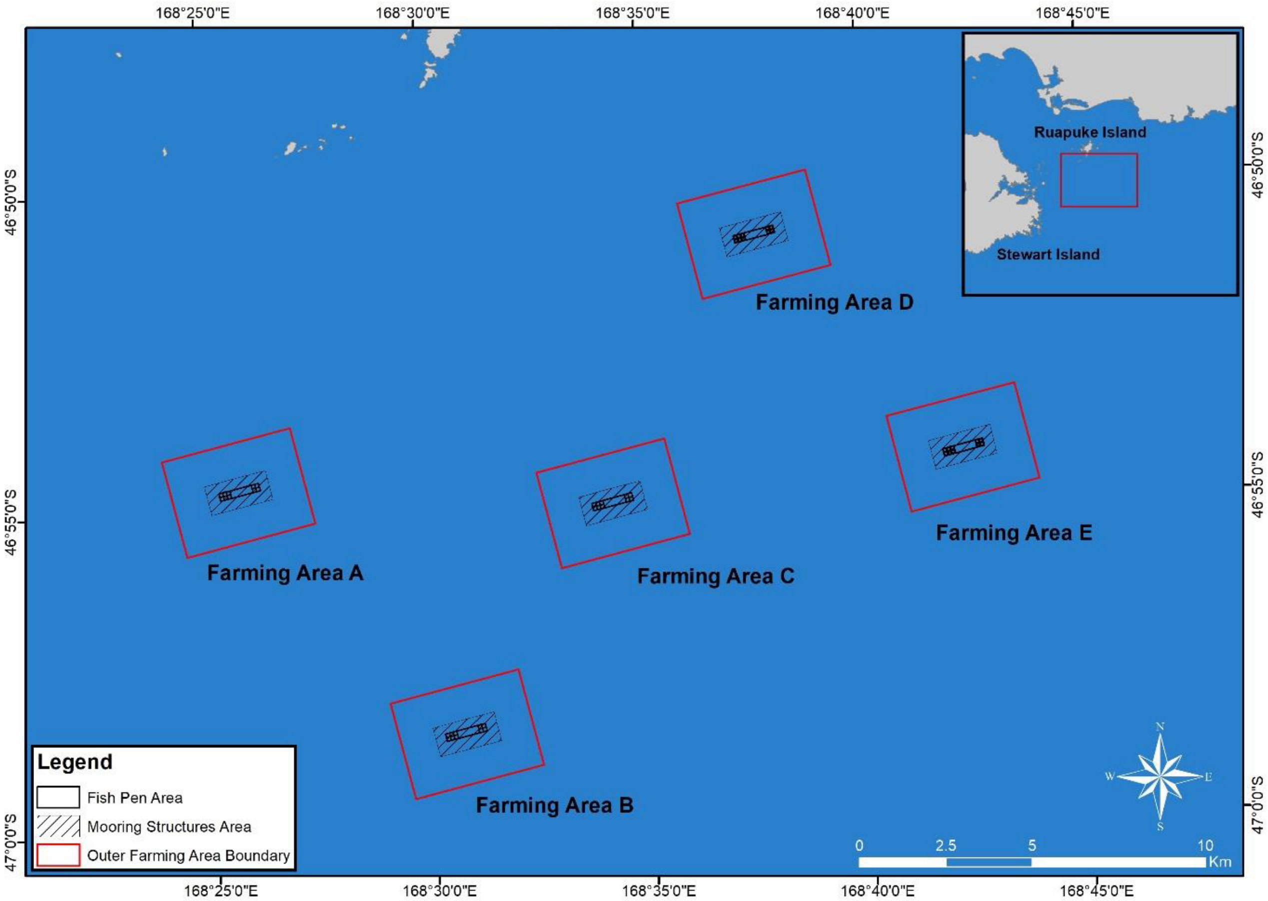

Fig. 1. Location of proposed salmon farming development.

Risks are discussed qualitatively, in preference to undertaking a systematic risk assessment in which the likelihoods and consequences of the hazards identified, and their associated uncertainties, would be considered. In part this approach reflects that situation-specific uncertainties can be high, such that it is more useful to focus on the range of possible scenarios and ensure that effective management is in place to minimise risk (irrespective of the perceived magnitude) to an acceptable level.

A particular focus in this report is to describe the extent to which the project proposal exacerbates risk above and beyond the 'baseline' level represented by existing activities, as this knowledge informs the extent to which management of proposal-related risk is likely to have a benefit.

2. BIOSECURITY CONTEXT AND ROLE OF AQUACULTURE

2.1 BIOSECURITY CONTEXT IN NEW ZEALAND

Human activities in the marine environment, especially trans-oceanic movements of vessels, have long been recognised as a major pathway for the inadvertent spread of marine organisms well beyond their natural dispersal ranges (Chilton 1910; Elton 1958; Skerman 1960). Around 214 non-indigenous species (NIS) have been introduced to New Zealand and subsequently become established (MFE 2019), most of these initially into ports and harbours via shipping-related mechanisms such as ballast water discharge and hull biofouling (Hayden et al. 2009b).

NIS are now considered a major threat to marine environments globally, in part because once they become established, they can seldom be eradicated. As such, for the small subset of NIS that become problematic (i.e. marine pests), any adverse effects that arise are typically irreversible. Moreover, since most introduced species are spread beyond their point of initial introduction via human activities (e.g. domestic vessel movements), or by the dispersal of microscopic life-stages in water currents, adverse effects can occur locally, regionally, and nationally (Dodgshun et al. 2007). In other words, the impacts of marine pests do not become diluted with distance from a point source in the sense that 'traditional' contaminants do.

To reduce biosecurity risks at the international border, New Zealand has in place strict standards for ballast water discharge (IHS 2015) and specifies allowable levels of biofouling on the hulls of arriving vessels (CRMS 2018). By contrast, there are no comprehensive national-level controls for the domestic activities that facilitate the spread of marine pests. As such, existing marine pests, and those introduced to New Zealand in the future (i.e. despite the border standards that are in place), are likely to further spread nationally. In this respect, vessels movements and other human activities have the capacity to not only spread pests at a greater rate than could naturally occur, but also to transport them to locations that they may never reach by natural mechanisms.

The ways that different life-stages of marine pests may facilitate human-mediated or natural dispersal are described in Appendix 1, of which dispersal by water-borne planktonic life-stages is of particular importance. The natural dispersal capacity of many pests is limited to within a short distance from established populations (e.g. 10s of metres to a few kilometres). Accordingly, the initial pattern of spread for new marine pest introductions to New Zealand is typically among ports, harbours and other vessel hubs (e.g. marinas), and thereafter to regional locations by secondary vectors such as recreational vessels. Spread by natural dispersal also contributes to within-region spread, but is of particular importance for facilitating the establishment of local populations of pests, sometimes at problematic densities (Forrest et al. 2000; Fletcher et al. 2013b).

For these reasons, preventing regional establishment through effective management of risks from human transport mechanisms is the cornerstone of effective marine pest biosecurity. Critical to addressing domestic spread is the management of risks from marine pests that are associated with hull biofouling (Fig. 2).

Fig. 2. When vessel hulls are not maintained, biofouling can be a significant contributor to regional and national marine pest risk

2.2 AQUACULTURE AS A CONTRIBUTOR TO MARINE BIOSECURITY RISK

Aquaculture in New Zealand is highly unlikely to 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 farming regions by vessels and other pathways.

Examples of marine pests associated with aquaculture are shown in Fig. 3, and Fig. 4 conceptualises the main ways that finfish aquaculture can contribute to marine pest risk, which are all relevant to the present proposal. Fig. 4 highlights that 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 key processes are as follows:

1. Risk pathways associated with aquaculture activities lead to marine pest introductions to farming areas 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 farming 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 (Acosta & Forrest 2009; Darbyson et al. 2009; Sinner et al. 2009; Fletcher et al. 2017). 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 (see Fig. 3). 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 impact farming operations and exacerbate spread to the wider environment. The latter may be enabled by natural dispersal processes (via mechanisms such as described in Appendix 1) or through interactions between the pest reservoir and secondary transport vectors.

3. Farm wastes may create environmental conditions suitable for marine pests

Marine farm waste production 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).

Appendix 2 provides further detail and examples of these processes with respect to aquaculture activities in New Zealand, in particular finfish farming.

Fig. 3. Aquaculture structures provide habitats on which pests can become abundant. Left: Mediterranean fanworm *Sabella spallanzanii* on mussel crop (K. Walls, MPI); middle: Asian kelp *Undaria pinnatifida* on mussel farm float (B. Forrest); right: sea squirt *Didemnum vexillum* occluding salmon farm nets (B. Lines, Diving Services NZ)

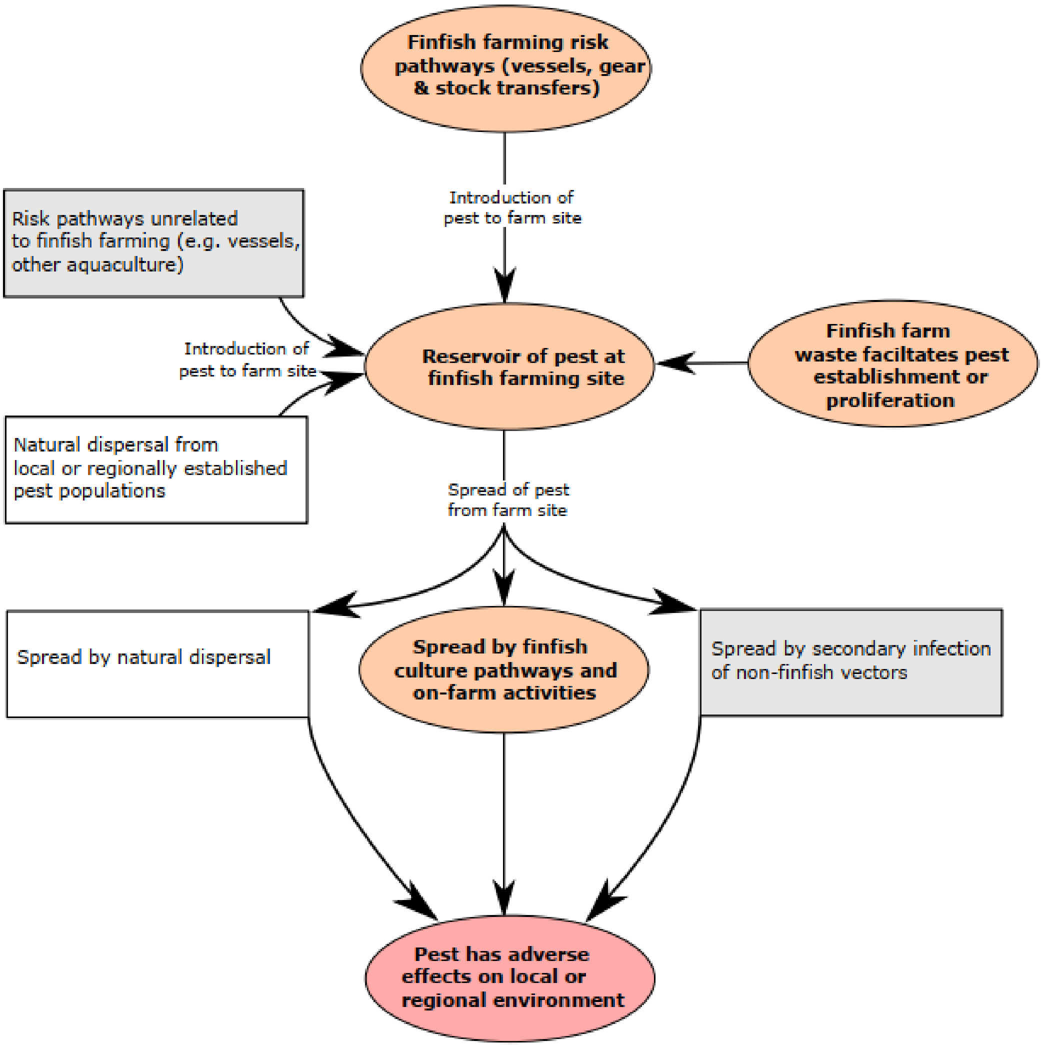

Fig. 4. Overview of the main stages associated with the potential for adverse marine pest effects (red) from finfish aquaculture (orange). The rectangles illustrate that risks may arise from anthropogenic (grey) and natural (white) mechanisms of pest introduction and spread that are unrelated to finfish aquaculture.

3. BACKGROUND AND CONTEXT FOR ASSESSMENT OF EFFECTS

Understanding the existing marine pest profile of Southland in terms of risk species, risk activities, at-risk values, and existing management approaches, underpins the assessment in Section 5 of the incremental risk posed by the proposed development and the likely benefits of proactive management.

3.1 EXISTING MARINE PESTS AND THEIR MANAGEMENT

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; Table 1). An MPI marine pest list includes all of the SRPMP species except the sea squirt *Didemnum vexillum*, and lists five additional species that have not yet been recorded in New Zealand (MPI 2015).

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, despite initial eradication attempts in these locations (Hunt et al. 2009). Active population control programmes for *Undaria* are currently in place in Breaksea Sound and Chalky Inlet in Fiordland (Gnanalingam & Hepburn 2019). *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 (Appendix 3), of which the 'Southern *Undaria* Exemption Area' appears to encompass the proposed farming locations.

The other pests listed in Table 1 have not been recorded in Southland and are classified as 'exclusion programme' species, for which the management goal is to prevent establishment and spread in the region. However, except for Fiordland, there are no pathway management measures in place specifically designed to protect the region from marine pests. For the Fiordland coastal marine area, special measures have been developed to manage marine pest risk from vessel biofouling, equipment and residual seawater such as bilge water (SRC 2017).

While it is assumed that the six exclusion species are absent from the region, Environment Southland does not have a comprehensive inventory of NIS, with only Bluff Harbour and Milford Sound having been subject to intensive biological surveys. For example, in addition to *Undaria*, a biological baseline survey conducted in Bluff Harbour in 2003 (Inglis et al. 2005) described a total of 330 species or higher taxa, of which 12 species were non-indigenous species, 28 were 'cryptogenic' (species whose geographic origins are uncertain) and 83 were of indeterminate taxonomy. None of the 12 NIS found in the 2003 survey are regarded as marine pests.

Bluff Harbour is also one of 11 sites nationally that form a 6-monthly Marine High Risk Site Surveillance (MHRSS) programme funded by MPI (Growcott et al. 2019). That programme involves biannual surveillance for target marine pests in a range of habitats in Bluff Harbour and Awarua Bay. Other than *Undaria*, no designated marine pests have been detected during surveillance, although the Japanese skeleton shrimp *Caprella mutica* was recorded in 2018/19 (Growcott et al. 2019), which is a species regarded as having potential to cause problems.

Outside Bluff Harbour, the only intensive baseline biological survey appears to have been in Milford Sound, where a 2006 survey recorded no NIS among 390 species or higher taxa that were described (Inglis et al. 2008). There appear to have been no comprehensive biological surveys conducted in the vicinity of the proposed salmon farming areas, with the exception of the benthic surveys conducted for the application. Nor have there been surveys in BGB where aquaculture is already well-established.

Table 1. Marine pests listed in the Southland Regional Pest Management Plan and their recorded NZ distribution. To date only *Undaria pinnatifida* has been recorded in Southland. Except for *Didemnum vexillum*, all species are MPI-designated marine pests. There are five additional species in the MPI (2015) marine pest list that have not yet been recorded in New Zealand.

Scientific name	Common name and/or group	Reported NZ distribution	Example
a. Species recorded in Southland			
Undaria pinnatifida [1,2]	Japanese or Asian kelp/Large brown seaweed	Widespread nationally, with recorded Southland locations being Big Glory Bay/Paterson Inlet, Half Moon Bay, Bluff Harbour, Breaksea Sound & Chalky Inlet	
b. Species recorded in New Zealand but not in the Southland region			
Charybdis japonica	Asian paddle crab	Whangarei, Bay of Islands, Kaipara, Auckland (Waitemata)	
Didemnum vexillum	Colonial sea squirt	Widespread in many ports and harbours nationally, including around the Top of the South Island	
Eudistoma elongatum	Australian droplet tunicate/Colonial sea squirt	Northland east coast, Kaipara Harbour, Waiheke Is	
Pyura doppelgangera	Solitary sea squirt	Northland west coast and Bay of Islands	
Sabella spallanzanii [3]	Mediterranean fanworm/ Tubeworm	Northland (Whangarei, Opua), Hauraki Gulf, Waikato (Firth of Thames, Coromandel), Tauranga, Gisborne, Tasman, Nelson, Marlborough, Lyttelton, Dunedin	
Styela clava [2]	Clubbed tunicate/ Solitary sea squirt	Northland (Whangarei, Bay of Islands, Tutukaka), Kaipara, Hauraki Gulf, Waikato (Firth of Thames, Coromandel), Tauranga, Wellington, Tasman, Nelson, Marlborough, Lyttelton, Dunedin	

[1] *Undaria pinnatifida* listed in SRPMP as a 'Containment' pest, while other species are listed as 'Exclusion' pests.

[2] *Undaria pinnatifida* and *Styela clava* have been declared as unwanted organisms.

[3] *Sabella spallanzanii* is unwanted and also a notifiable organism under S45 of the Biosecurity Act.

Based on the recognised role of aquaculture in the spread of NIS (Section 2.2, Appendix 2), and descriptions of NIS and marine pests associated with aquaculture structures elsewhere in New Zealand (Woods et al. 2012; Atalah et al. 2016), it is conceivable that surveys in BGB could reveal a greater suite of NIS than currently recognised for the Southland region (see also Section 3.4).

3.2 KNOWLEDGE OF ACTUAL AND POTENTIAL IMPACTS OF MARINE PESTS

There have been no comprehensive studies of marine pest impacts 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 impacts, 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 (Forrest & Taylor 2002; Fletcher et al. 2013a). 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 impacts are summarised in Table 2. 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.
- Effects on the natural character of coastal ecosystems.

Some of the most dramatic effects internationally have arisen through impacts on aquaculture, especially those caused by high abundances of biofouling. For example, the SRPMP/MPI pest *Styela clava* had a devastating effect on mussel aquaculture in parts of eastern Canada (Ramsay et al. 2008), but effects of a comparable magnitude have not been observed in New Zealand thus far.

Nonetheless, biofouling impacts on salmon and shellfish aquaculture are significant in parts of New Zealand, with problems not always due to designated pest species. For example, native biofouling organisms can also be operationally significant where they thrive in the novel habitat provided by floating aquaculture systems (Forrest et al. 2014). Examples of NIS and other problem species in New Zealand aquaculture include:

- Spat or crop loss from lines, described for sea squirts such as *Ciona* spp. and *Didemnum vexillum* in Marlborough (Fletcher et al. 2013a). It has been estimated that mussel farms in the Marlborough Sounds lose up to 15% of their seed-stock through biofouling (Hembry 2008), although the impact may be even greater.
- Economic losses due to blue mussel (*Mytilus galloprovincialis*) biofouling on mussel farm crops in Marlborough was estimated at ~$25 million/year, which represents around 10% of the regional value of the mussel industry (Forrest & Atalah 2017).
- Finfish stock losses, health declines, and product value downgrades, have resulted from biofouling by anemones and/or hydroids in the Marlborough Sounds. These species release stinging cells which appear to contribute to skin lesions and secondary infections in fish (Atalah & Smith 2015).
- Effects on product harvesting and processing (e.g. physical interference) and/or loss of market value of product have been described for *Undaria* (Sinner et al. 2000), the sea squirt *Styela* (McFadden et al. 2007) and a range of other species (Heasman & de Zwart 2004; Jeffs & Stanley 2010).
- Impacts to infrastructure through stress associated with increased weight or drag have been described for *Undaria* in Marlborough (Sinner et al. 2000).
- Costs associated with control and mitigation efforts have been incurred for specific pest species (Pannell & Coutts 2007; Hunt et al. 2009), and for biofouling in general.

Table 2. Summary of habitats and potential impacts 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*.

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

Adverse effects in New Zealand are not limited to aquaculture. For example, the kelp *Undaria* is considered to change the natural character of coastal habitats (Sinner et al. 2000). This type of effect is particularly noticeable where *Undaria* establishes in locations devoid of other canopy-forming brown algae. However, a recent review concluded that *Undaria* did not lead to significant changes in most of the significant natural habitats of canopy-forming algae that it invaded (South et al. 2017).

Like *Undaria*, the sea squirts *Eudistoma* and *Pyura*, and fanworm *Sabella*, can also be conspicuous in natural ecosystems due to the high densities they achieve, compounded for *Eudistoma* and *Pyura* due to their ability to establish intertidally. For *Sabella* and *Pyura*, current research is considering the extent to which high densities may lead to structural or functional changes in invaded ecosystems (pers. comm., Javier Atalah, Cawthron Institute).

In terms of invasiveness in natural habitats, probably the most dramatic example among the SRPMP pests has been recorded overseas for the sea squirt *Didemnum vexillum*. In deep-water (40-65m) natural seabed habitats of Georges Bank located more than 200km offshore from the coast of the north eastern United States, this species (formerly referred to as *Didemnum* sp.) was recorded as covering a seabed area of 230km^2 (Valentine et al. 2007). A subsequent study concluded that *Didemnum* was able to out-compete other epifaunal and macrofaunal taxa in this location, and had a significant impact on the species composition of the benthic community (Lengyel et al. 2009).

3.3 EXAMPLES OF REGIONAL VALUES POTENTIALLY AT RISK

Separate reports prepared for this application describe the values of the development area and wider environs. Examples of these values include:

- Significant existing aquaculture focused in BGB, with 35 consented farms that have been developed along both sides of the bay since the early 1970s.
- Significant fishery values, including the dredge oyster fishery, and fisheries for abalone, lobster and various finfish species (Middleton 2019).
- Very high ecological and conservation values. For example:
    - There are 11 marine reserves within the Southland coastal marine area, one being in Paterson Inlet, with all the internal waters of Paterson Inlet excluding the marine reserve and BGB included in the Te Whaka ā Te Wera/Paterson Inlet Mātaitai reserve.
    - All of Stewart Island (except BGB) has been identified by the Department of Conservation as having values of regional or national significance.
    - The area has diverse coast that is characterised by rocky headlands, estuaries and lagoons, some of which contain endangered or significant species and ecosystems.
- Foveaux Strait supports a diverse, abundant seabird community (McClellan 2019).
- The region has a range of coastal values of cultural significance, and various recreational and tourism-based activities that benefit from attributes such as particularly high natural character.

Despite the absence of concrete evidence for adverse effects in most instances, it can be assumed that many of the above types of values are potentially at risk from existing or potential marine pests due to activities that exacerbate spread, on the basis that:

- Actual and potential marine pests, including the high-profile species listed in the SRPMP, have a range of actual or potential direct and indirect ecological effects, such as noted in the preceding section, and may impact a range of non-ecological values (see Table 2).
- These pest species inhabit many different types of environment (e.g. biofoulers, reef dwellers, soft sediment biota), and some of the species individually are habitat generalists; they can establish in soft sediment as well as hard substratum habitats, and in intertidal and subtidal zones.

3.4 EXISTING PROFILE OF RISK ACTIVITIES AND THEIR MANAGEMENT

Although geographically isolated, the Southland region and Stewart Island are reasonably well-connected domestically and internationally by vessel movements and other anthropogenic activities that could contribute to biosecurity risk. The existing consented mussel and salmon farms in

BGB represent a potential reservoir for marine pests. However, except for *Undaria*, as noted above in Section 3.1 it is unclear the extent to which other NIS are already established on these structures. Historically, inter-regional movements of vessels, equipment and seed-stock carried out to develop and operate the farms are likely to have been high-risk pathways for the introduction of new pests to the region. As such, it is possible that the existing farms already provide a reservoir for certain marine pests (actual or potential), and potential stepping-stones for their direct spread into adjacent high value habitats.

By comparison with the historic situation, biosecurity practices are now in place for the Southland industry. For example, as a condition of Sanford BGB mussel farm consents, wild mussel spat can be sourced only from Kaitaia weed (collected from 90-mile beach, Northland) and not high-risk source regions like Marlborough. Sanford also has a resource consent enabling transfer of spat from a Nelson Bay hatchery, but this represents a highly biosecure pathway.

Further practices have arisen from Controlled Area Notice (CAN) provisions that have been implemented by MPI (MPI 2017) to minimise the risk of introducing the parasite *Bonamia ostreae* into southern New Zealand. *Bonamia ostreae* is a threat to the dredge oyster fishery in Foveaux Strait. In overview, the CAN places restrictions on:

- The movement of various cultured shellfish into a 'Protected Zone' comprising the territorial seas of Otago and Southland (i.e. including Stewart Island and Foveaux Strait).
- The movement of various cultured shellfish and 'other goods' (including industry-related vessels and equipment) into or out of a 'Stewart Island Zone' extending 1nm from the main land area (but not encompassing the application area).

The CAN means that the specified industry-related movements are prohibited unless authorised otherwise by a permit and associated conditions. For example, movements of Sanford vessels, aquaculture equipment and seafood products into and out of the 'Stewart Island Zone' have rigorous requirements in terms of hull inspections and cleaning which are regularly renewed, and have been audited (pers. comm., Alison Undorf-Lay, Sanford; Appendix 4). CAN measures do not apply to non-industry vessels.

The wider area of the proposed development is well-connected by vessel movements, including from potential source regions for marine pests. While biofouling is a risk mechanism on all vessel types, in the case of ships and some other large vessels described below, there exist additional risk mechanisms in which viable organisms may be released; for example, via discharge in ballast water or from vessel sea chests (Coutts & Dodgshun 2007; Hewitt et al. 2009). Although border controls on ballast water will reduce risk from international vessels, risk is unlikely to be negated. This is due to the incomplete effectiveness of the main current management approach based on mid-ocean ballast water exchange (Taylor et al. 2007). In addition, there are no controls on ballast water from ships travelling between domestic New Zealand ports (Sinner et al. 2012).

The application area is transited by vessels from many locations. Fig. 5 provides a density map of vessel traffic to illustrate the international (Fig. 5a) and regional (Fig. 5b) connectedness of the application area by vessels of all types. In the immediate environs of the project area, Ruapuke Island has vessel activity associated with the few houses on it, and for activities such as recreational and commercial/charter diving and fishing.

A biofouling introduction (e.g. via vessels, lobster pots) most likely explains the presence of *Undaria* in that locality, as *Undaria* does not have the capacity to spread there by natural dispersal, unless by fouling associated with drifting debris. Research from New Zealand suggests that natural spread to places such as Ruapuke would almost certainly be precluded by the large distances (10s of kms) to well-established populations of *Undaria* in BGB and Bluff, combined with expansive areas of deep water and soft-sediment habitat (Forrest et al. 2000; Sinner et al. 2000).

Beyond the immediate project area, there is considerable existing commercial vessel activity in BGB and Paterson Inlet, summarised in Appendix 5. 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, water taxis and private recreational vessels, sometimes arriving from out of the region.

Compared with many other locations in New Zealand, recreational vessel numbers appear to be

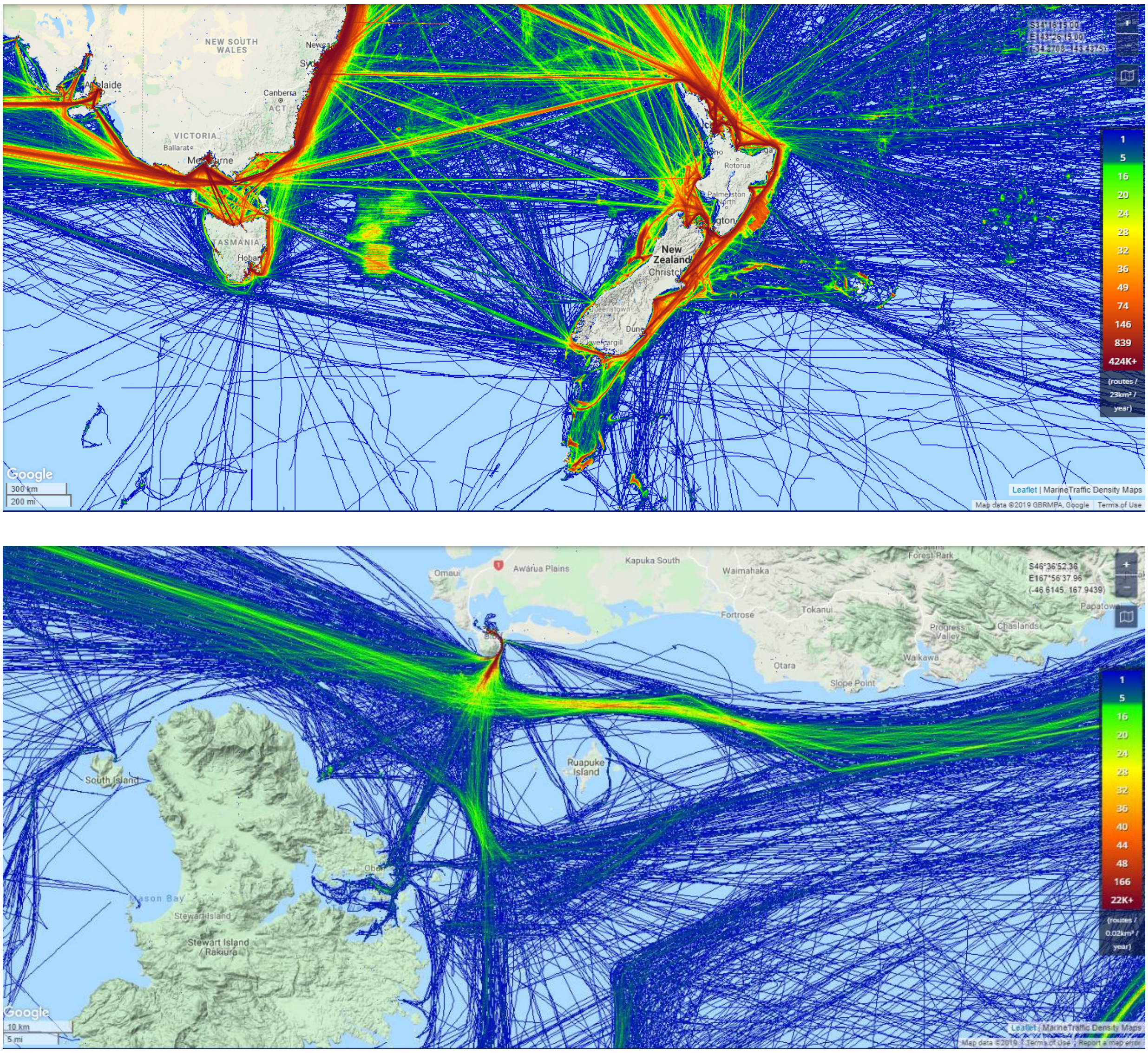

Fig. 5. Vessel pathway density map based on 2017 data, with international (routes/23km²/yr; top) and regional (routes/0.02km²/yr; bottom) pathways illustrating connectedness of the application area by vessels (not including vessels without tracking systems, i.e. excluding most recreational vessels). On bottom map, proposed salmon farm area is to the south of Ruapuke Island (source of images: www.marinetraffic.com).

quite low across the Southland region as a whole (Dodgshun et al. 2007). Despite this situation, low numbers of recreational vessels (those moored or berthed in-water) may nonetheless be significant as a potential pathway for marine pest spread (Acosta & Forrest 2009; Piola & Forrest 2009; Brine et al. 2013; Forrest 2019). Key risk factors include their propensity to transport viable biofouling, and voyage patterns that can involve visits to relatively remote and pristine coastal areas and include direct interactions with aquaculture (e.g. recreational boats may tie off to marine farms to fish).

Additionally, there are many vessel pathways to and from Bluff, and its associated hub of domestic and international vessel activity. This activity includes vessels of all sizes and types, such as bulk carriers, container ships, tugs, fishing vessels, dredges, tourist vessels and recreational boats (Dodgshun et al. 2007; Hayden et al. 2009a).

Information in the Southport 2018/19 annual report (https://southport.co.nz/assets/reports) indicates that many vessels arrive in Bluff from outside the region for import of alumina, petroleum products, fertiliser, acid, stock food and cement; and export of aluminium, timber, logs, dairy, meat by-products, fish and woodchips. Vessels arrivals are from most ports in New Zealand, and international vessels arriving directly or indirectly from ports in Australia, Europe, Asia and the United States. Data from 2000-2005 reported by Hayden et al. (2009a) indicated 1,117 arrivals of merchant vessels >99 tonnes to Southport, of which a high proportion (42%) were bulk carriers. More recent data from Southport indicates 352 ship visits to the port in 2018/19. On top of this inter-regional or international activity are within-region movements of vessels, such as those associated with fishing (e.g. dredging, trawling) and aquaculture, at least two commercial charter operators, the Foveaux Freighter, and a ferry that operates between Bluff and Stewart Island.

There is limited management of the non-industry risk pathways operating in the proposal area or further afield regionally. Vessels arriving from international source regions would be subject to border standards for biofouling, ballast water and sediment. In the project area and environs, the Southern *Undaria* Exemption Area referred to above apply (Appendix 3). Further afield, vessels operating in the Fiordland Coastal Marine Area are subject to Environment Southland's Fiordland Marine Regional Pathway Management Plan, which has strict rules to manage vessel biofouling, equipment and on-board seawater.

4. ASSESSMENT OF EFFECTS OF PROPOSED DEVELOPMENT

4.1 OVERVIEW OF PROPOSED DEVELOPMENT

The proposal is to develop five salmon farms. Each farming area will consist of ten circular pens of about 120m circumference, with the area per block being not more than 20ha plus warps and anchors. It is anticipated that production would be about 5,000T per farm, and 25,000-27,000T overall at full production.

Pens would be moored in place using screw anchors with chain/rope warps. Growing nets will extend from the surface to 30m depth, possibly with a predator exclusion net surrounding each pen if required. Juvenile salmon for stocking the farms will be sourced from land-based freshwater hatcheries or from Sanford BGB Bay farms. Each farming area will have one permanently moored service barge that will be used as working platform housing feed and other equipment.

Water depths across the production area are 52-80m and pens will be over primarily fine-sand sediments containing little shell material (ADS 2019b, a). The area is subject to moderate currents, of typically 0.2-0.4m/s, with peaks of >1.1m/s around Ruapuke Island (ADS 2019b; Lim et al. 2019b). The wave climate is also quite strong, with wave heights of up to 10m.

4.2 GENERAL APPROACH TO THE MARINE PEST ASSESSMENT

The assessment below 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 farm and its environs. At this local scale, farm development will establish a hub of activity and provide an extensive surface area of structures for biofouling, which does not currently exist; the closest area of existing marine farming is in BGB ~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 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 area 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 these 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 area 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 subsections below provide the detailed evaluation of risk based on the general approach outlined above. A subsequent section (Section 5) provides a synthesis of this material.

4.3 POTENTIAL MARINE PEST RISK PATHWAYS AND THEIR SIGNIFICANCE

4.3.1 Identifying high-risk pathways

In general terms, any new development that involves additional movements of vessels and other transfer activities is expected to lead to some level of incremental biosecurity risk. However, based on assessments of biosecurity risk from finfish culture developments in the Waikato region (Forrest et al. 2011) and Marlborough (Forrest 2011), transfer pathways that should be given special attention have the following attributes:

1. **Origin:** the most significant pathways originate in source regions known to be infected by recognised high risk pests that do not already occur in the recipient region.

2. **Novelty:** Pathways that involve novel mechanisms of transfer that do not already occur as a result existing regional activity may be of particular interest.
3. **Magnitude:** Of interest are situations where there is an increased 'mass load' of potential pests due to:
   i. A high frequency of pathway activity relative to existing anthropogenic activities.
   ii. The occurrence of anthropogenic activity in locations where there is negligible risk due to the natural dispersal of pests from established populations.

In the context of these factors, the key pathways relevant to the proposal for which marine pest risk needs to be considered relate to both initial farm development and ongoing operations. The risk associated with the proposed project operation would arguably be most significant if a new pest was introduced into the area. This highlights that the most important pathways to manage are those with the potential to introduce new pest species from other regions, especially pathways directly to the farm environs. Accordingly, of critical importance will be effective measures to ensure that pathway risks relating to the proposed activity are reduced to a level that is negligible and acceptable in the broader context.

In terms of understanding the need for risk management, it should be noted the mechanisms described earlier for the transfer of pests with entrained water such as bilge, or associated with sediments (e.g. on anchors), may arise as part of project operations. Contaminated dive gear represents another possible yet uncertain risk. For these and other risks that relate to the 'topside' of operational vessels and equipment, stringent biosecurity protocols for disease risk management will be incorporated into a Fish Health or Biosecurity Management Plan (see Section 5.2). It is assumed for present purposes that disease risk management approaches (including but not limited to *Bonamia* management) will be effective for mitigating any associated marine pest risk, as they will involve cleaning and disinfection procedures that would be effective against all pest life-stages. Accordingly, the focus below is on specific risks from marine pests on submerged surfaces (i.e. below the water line) of vessels or equipment, which arise primarily as a result of biofouling.

4.3.2 Farm development and operational risk pathways

Infrastructure and equipment

Initial farm development will involve the installation of submerged infrastructure such as pontoons, nets, anchor warps (rope, chain, etc) and other materials. It is unclear exactly where this infrastructure will be sourced from and how it will be moved to the farming areas. The most important consideration is that the movement of such materials does not introduce significant new risks. The issue with contaminated equipment is that long-term deployment can enable any associated marine pests to grow and reproduce (Appendix 2). In theory, even gear that is only briefly in contact (e.g. for a matter of days) with pest-infected water in its source region has the potential to be a pathway of spread to other locations (Forrest & Blakemore 2006; Schimanski et al. 2016).

Infrastructure risk was exemplified by a pest management case study of *Didemnum vexillum* in the Marlborough Sounds by Forrest and Hopkins (2013). The spread of this species beyond a single bay near Picton occurred when *Didemnum* dispersed from an infected international barge to a nearby finfish farm pontoon being temporarily stored in the same bay. The pontoon became unknowingly infected with *Didemnum* (in a microscopic stage) and was towed ~30km in-water to a finfish aquaculture location where the sea squirt subsequently proliferated on the farm structure, spread by natural dispersal to an adjacent mussel farm, and thereafter to other mussel farms in the new location. In at least one other location the same species caused significant impacts on finfish culture operations, by occluding farm nets and impeding water and oxygen flow through the farm (see Fig. 3).

To minimise such risks in relation to the proposed project, infrastructure and equipment needed for farm development and any ongoing maintenance (including dive equipment), needs to either be new and not exposed to source-region risk, or treated in such a way as to ensure it is pest-free before it is transported to the farming areas.

Vessel movements

Vessels will be used for initial farm development, and thereafter for routine and regular transfer of personnel, equipment and fish feed to the farms, as well as for fish stocking, and harvest operations.

For initial farm development, it is likely that specialist vessels from out of region will be used; for example, for screw anchor installation. Likely source regions include Nelson and Marlborough, where two specialist vessels are based that serve the aquaculture industry nationally. Those regions include SRPMP pests that have not been reported from the Southland region, specifically the fanworm *Sabella spallanzanii* and sea squirts *Styela clava* and *Didemnum vexillum*. The top of the South Island region also has a range of other potentially problematic biofouling species not listed in the SRPMP and not recorded as being present in the Southland region (Morrisey & Miller 2008; Forrest et al. 2014). The recognised and potential pest species are all highly amenable to transport via hull biofouling. As such, it would be appropriate that a BMP specify hull maintenance practices and standards for such vessels that ensure risks are mitigated to an acceptable level (see Section 5.3).

In terms of operational vessels and related biofouling risk, the development will involve vessels that move: (i) between Bluff and the new farming areas and never into BGB; (ii) between Stewart Island and the new farming areas and never into BGB; and (iii) between Bluff and the new farming areas, and occasionally into BGB. Examples include:

- **Personnel transport:** Vessels transporting personnel to and from the proposed farms will likely be based in Stewart Island.
- **Delivery of fish feed to the farming areas and transport of harvested fish for processing in Bluff:** Sanford plan to use a lease vessel initially and then a custom-built vessel which will be based in Bluff. It has no need to steam to Stewart Island.
- **Transfer of stock:** Stock are expected to be sourced from land-based hatcheries and transported by road to Bluff and then by vessel to the farm. Some transfers of fish may come off the BGB smolt farm. All fish transfers require MPI permits, and vessel movements currently require a CAN permit.
- **Net cleaner:** This operation will use a vessel(s) that will likely be moored in Stewart Island overnight and travel to the new farming areas. It will only go to Bluff for survey and servicing.
- **Work boat, heavy lifting and moorings:** This vessel will move between Bluff and the new farming areas, moored overnight in Stewart Island. It could be used, with a CAN permit, to assist in BGB when shifting farms.
- **A vessel for collection of mortalities:** This will be a small vessel that will move between Bluff and the new farming areas. It would not go into BGB.

Note that the barge associated with each farming area will function primarily as a working platform rather than an active vessel; however, it may occasionally be defouled on site and travel to Bluff for maintenance.

Although the above within-region movements may not appreciably add to the regional vessel activity risk profile (see Fig. 5b), they involve interactions with a new hub (i.e. at the proposed farming areas); hence, it is important that they be managed in such a way that regional vessels do not transport pests from their origin or home port to the proposed farming areas, or vice versa. Although the only SRPMP pest reported in the region is *Undaria*, it was noted above that BGB has likely been exposed to introductions of other NIS over the long period of aquaculture there. Accordingly, as for out-of-region aquaculture vessels, it will be important to mitigate any potential incremental level of marine pest risk from regional vessels by ensuring that they adhere to stringent hull biofouling standards as part of a BMP.

In the above context, it should be noted that the risk profile of vessels will in part be linked to their operational activity. Some vessels are inherently low risk due to their operating profile. For example, fast-moving vessels typically used for personnel transport are often in regular use, and physical shear forces at high speeds prevent the accumulation of biofouling, except in hydrodynamically protected areas such as bow thruster tunnels or stern trim tabs (Coutts et al. 2010a; Forrest 2017; Forrest 2019).

Conversely, greater attention to biofouling risk and management will be important for vessels associated with the operation whose activity profile makes their entire hull surface vulnerable to biofouling and/or marine pest transport. A classic example is provided by slow moving vessels like barges. These vessels can accumulate fouling if they spend extended periods of time idle. Moreover, their typically slow voyage speeds enables transport survival of fouling due to low physical dislodgement forces (Coutts & Forrest 2007; Coutts et al. 2010b; Hopkins & Forrest 2010).

Stock

It is assumed that the freshwater in which stock are transferred from hatcheries is of no relevance from a marine pest perspective. However, if stock transfers in seawater were undertaken (i.e. smolt from BGB), treatment of the water would need to be addressed. Raw or inadequately treated seawater could theoretically carry potential pest species, in particular as microscopic planktonic life-stages (e.g. invertebrate larvae or fragments, or seaweed spores). These are the same life-stages that are also important in the transfer of harmful organisms in ballast and bilge water. As any such transfers would need to be managed for disease risk, it is assumed that any concurrent marine pest risk would be simultaneously negated, for reasons described above.

4.3.3 Comparison of proposed risk pathways with other sources of risk

The purpose of identifying and managing pathways associated with the proposed operation is to minimise the risk that marine pests are introduced to the farming areas or elsewhere in the region.

As highlighted in Fig. 4, to understand the merits of pathway risk management for proposal-related activities, it is necessary to understand existing sources of risk that could also lead to the spread of marine pests. As already noted, except for marine farming resource consent conditions and *Bonamia* CAN restrictions on the aquaculture industry, there are no general pathway management measures in place for Southland that apply to the proposal area. As such, the region will be subjected to ongoing risk from activities with the potential to introduce new marine pests from external sources.

In this regional context, any incremental risk from the proposal is likely to be relatively minor. However, this situation does not negate the importance of having effective management measures in place for the development, given that activities will likely involve vessel and equipment movements directly to the farming areas from high risk source regions.

When considered within-region, management of project risk pathways is also desirable, even in the absence of comparable measures for other companies or activities operating in other areas of Southland. This reasoning arises from the assumption made in Section 4.2 that the isolated and wave-exposed nature of the proposed farming areas likely means it has a low present susceptibility to the spread of marine pests from existing or potential regional populations. As described for *Undaria*, the distance from potential pest populations (e.g. in BGB), combined with expansive areas of deep soft-sediment habitat and a wave-exposed environment will act as a 'firebreak' across which many marine pests would be unlikely to spread (Forrest et al. 2009). *Didemnum vexillum* is the only SRPMP species that appears to have at least some capacity to spread in offshore environments.

In general, however, if risk pathways are effectively managed so that the proposed farming areas do not become reservoirs for marine pests, there is an opportunity to protect both the industry operation and the environment in the vicinity. Ideally of course, comparable management efforts would be required of all exacerbators of regional risk, so that any special measures put in place for the project are not undermined by the uncontrolled spread of pest species.

4.4 FARM ENVIRONS AS PEST HABITATS AND RESERVOIRS FOR SPREAD

4.4.1 Background

There is a well-recognised role of artificial structures, including marine farms, as foci for pest establishment, and as reservoirs or stepping-stones for their colonisation of suitable natural habitats within their dispersal range (Ruiz et al. 2009; Simkanin et al. 2012; Forrest et al. 2013).

Moreover, there is recognition that as pests become more locally abundant, the increased 'propagule pressure' due, for example, to increased reproductive output of algal spores or invertebrate larvae, concomitantly increases the likelihood of further spread (Ruiz et al. 2000; Johnston et al. 2009; Lockwood et al. 2009; Simberloff 2009).

As described in Section 2.2 (see also Appendix 2), key processes of spread from locally enhanced pest populations on farm structures or their environs are natural dispersal to the seabed or other among structures (including other marine farms), secondary movement of infected vessels or equipment associated with culture operations, or infection of other anthropogenic vectors.

In the context of the project proposal, for any pests that spread to the proposed farming areas, whether they establish depends on the suitability of habitats in the recipient environment. Successful establishment implies that a species can survive and reproduce to form a viable self-sustaining population. For new pest species originating from external locations, one of the initial main considerations is whether the seawater temperature range is suitable for the pest to complete its life cycle.

The most conservative assumption for present purposes is that sea surface temperatures in Foveaux Strait (~10^{o}C winter to 15 ^{o}C summer) are likely to be suitable for all of the SRPMP pests, although for some species this seasonal range is probably approaching their lower limit. For example, the sea squirt *Eudistoma elongatum* is currently restricted to northern New Zealand, but is able to grow and reproduce at 14°C, with colonies able to survive colder winter months as 'buds' (Page et al. 2011).

Assuming temperatures are suitable, establishment potential and likelihood of adverse effects from salmon farm pest reservoirs depends on the abundance of the pest and whether high value habitats suitable for establishment exist within dispersal range; which in turn depends on factors such as planktonic competency period, the speed and direction of water currents, the availability of suitable habitat, and ambient environmental conditions. In the case of the project proposal, the importance of the farming areas as reservoirs for further spread is limited by several factors, including the deep, relatively 'offshore' and high energy nature of the proposed farming environment, the physical characteristics of the seabed, and the spatial separation of farming areas from suitable natural habitats.

The detailed assessment on which the preceding conclusion is based is provided in the following subsections, in which the significance of farm reservoir populations is also discussed in the context of pre-existing levels of risk.

4.4.2 Farms as habitats

As noted above, pests with the capacity to inhabit the novel off-bottom environment provided by marine farms can become highly abundant, with the range of substratum types (e.g. rope, chain, floats) and orientations (e.g. vertical and horizontal surfaces) providing habitats that suit different species to different degrees (Connell 1999; Glasby & Connell 2001). However, most of the examples where marine pests (including SRPMP pests) have reached very high densities on suspended marine farms (e.g. Fig. 3) are from relatively sheltered low-energy near-shore environments.

By contrast, the proposed farms are in a high energy situation with significant wave exposure and strong currents. The few New Zealand examples where biofouling has been documented in such situations suggest that the capacity for development of prolific densities is less, and that typically coastal pests species such as those in the SRPMP list either do not occur or do not thrive (Hopkins & Forrest 2010; Atalah et al. 2016; Forrest & Zaiko 2016). In the Marlborough Sounds, for example, prolific densities of the sea squirt *Didemnum vexillum* have only ever established on structures in wave-sheltered low-current environments (B. Forrest, pers. obs.). In general, offshore structures are often dominated more by 'hard' fouling species such as bivalves and barnacles.

Nonetheless, the potential for SRPMP pests to establish on the proposed structures, should they be transported there, cannot be ruled out. Even if pests did establish, however, the development of significant reservoir populations would be mitigated by the likely need to manage biofouling levels for operational reasons, as currently undertaken by Sanford on their BGB farms. General defouling of structures may be necessary to: (i) reduce drag on infrastructure; (ii) reduce the potential role of filter-feeding biofoulers as reservoirs for parasites and pathogens; and (iii) reduce the load of potential stinging biofoulers such as anemones and hydroids (Atalah et al. 2013). In addition, specific regular defouling of growing nets (and predator nets if used) will be required to maintain water and oxygen flow, maintain water quality, and thereby reduce stress on farmed finfish.

4.4.3 Local scale pest spread: adjacent seabed as a habitat

Soft sediments beneath farming areas

Theoretically, marine pests could colonise the seabed beneath the farming areas as a result of direct release from infected vessels. However, a more likely route is indirect, with vessels infecting farms, leading to a reservoir pest population that facilitates subsequent spread.

As well as spread by planktonic dispersal, biofouling organisms may drop off to the seabed from structures passively (e.g. due to wave dislodgement), or through active defouling (e.g. scraping, water blasting) conducted as part of routine maintenance. As collection of defouled material is not feasible, such practices have the potential to contribute to the transfer of pests to seabed habitat.

However, results of research in a sheltered New Zealand harbour environment indicate that sessile organisms (or viable fragments) defouled to soft sediments may not necessarily survive and establish; with sediment type, sedimentation rate, turbidity, and predation among the environmental factors that determine survival of defouled material (Hopkins et al. 2011a).

Furthermore, although there have been no comprehensive comparative studies, it is generally evident that marine species incursions globally occur in relatively sheltered habitats (Cranfield et al. 1998; Inglis 2001), with the Georges Bank *Didemnum* situation described in Section 3.2 being one of very few examples of pest incursions in high energy open coastal environments.

In the case of the seabed beneath the proposed farming areas, irrespective of the dispersal/transport mechanism, the environment is unlikely to be suitable for any of the SRPMP pests and most other potentially problematic marine pest species. For example, the seabed depth at the proposed farming areas of 52m or more is beyond the range from which SRPMP pests, except *Didemnum vexillum,* are reported to occur (see Table 2).

Moreover, the benthic assessment report (ADS 2019a) reveals a sparse infaunal assemblage and few surface-dwelling mobile (e.g. sea stars, crabs) and sedentary (e.g. tube worms, sea squirts) epibiota. The latter likely reflects that the predominantly fine-sand habitat has very little shell material, hence a lack of hard stable substrata on which sedentary epibiota can attach.

As such, even *Didemnum* is unlikely to establish under these conditions. In the overseas Georges Bank scenario, although being a deep open coastal environment, *Didemnum* established in seabed areas characterised by relatively stable pebble and cobble habitat, which provided suitable surfaces for attachment and growth.

Adjacent rocky habitat

By contrast with the seabed beneath the proposed farming areas, the rocky coastal habitats around Ruapuke and other small nearby islands are more likely to be suitable as habitats for pest species, at least in their more wave-sheltered aspects. This situation is already evident in the occurrence of *Undaria* at Ruapuke.

The 30m isobath, which represent depths more suitable for marine pests (see Table 2), as well as rocky areas marked on a chart of the wider area, are ~7-8km northwest from the closest of the proposed farming areas (A & D; see Fig. 1). This distance will reduce the likelihood of spread of potential pests from these areas.

Based on the preliminary particle dispersion modelling being conducted as part of the application it appears that particles could encounter shallow shoreline habitat to the NW of the farming areas (i.e. habitat most suitable for marine pests) in <1day at typical current speeds of ~0.3m/s. However, the duration may be highly variable (e.g. because of tidal direction or the direction of wind-driven surface currents). The duration would nonetheless be within the theoretical competency period for some potential pest species; however, species like *Undaria* with short planktonic competency periods and a requirement for hard substrata on which to attach following their planktonic phase, would have limited or no capacity to spread beyond the farming areas. Even for species with longer larval dispersal capacity, the dispersion of modelled particles will likely over-estimate risk given that:

- Not all released pest propagules will reach suitable habitat due to factors such as natural mortality and predation while in the plankton.
- Further mortality will occur during the transition from a planktonic to benthic life-stages, and subsequently.
- For many solitary (i.e. non-colonial) pest species, establishing a viable self-sustaining population relies on reproductive adults being next to each other to ensure spawning success. Propagule dilution with distance from reproductive sources therefore reduces the likelihood of successful long-term establishment in many species.

In general, substantial variability in establishment success in marine systems is well documented

(Simberloff & Gibbons 2004), with successful species invasions less likely than might be theoretically expected.

To provide a context for the uncertain but probably minor incremental risk from the project proposal, it is important to reiterate the point made in Section 3.4 that Ruapuke and conceivably the other small adjacent islands are already subject to pressure from the introduction of established pests. At worst, the proposed development will add only a small increment to this existing risk profile, provided all reasonable efforts are made to manage risk pathways and control on-farm biofouling.

4.4.4 Pest spread beyond local scales

Secondary infection of vessels and other vectors

As well as natural dispersal to high value habitats directly from the farming areas and related activities, there remains the possibility of secondary infection of vessels and other vectors, leading to pest spread beyond local scales. The extent to which this type of interaction with non-industry vectors might arise is unknown but likely to be low.

The most important secondary pathways to manage are movements of vessels and equipment associated with salmon farm operations away from each of the proposed farming areas, especially to locations outside the application area (e.g. vessel movements to processing locations or home ports). These activities can be addressed by the BMP which will need to be developed prior to start of installation.

Natural dispersal beyond local scales

In terms of long-distance natural dispersal, the constraints discussed above for local dispersal and establishment similarly apply. Furthermore, in Section 4.3.3 it was noted that the proposed farming areas were relatively isolated from pest spread from likely regional sources such as BGB, and the reverse is also true. Even in the event that pests established on farm structures or locally, it is unlikely that they would successfully spread naturally into high value locations such as BGB and wider Paterson Inlet. Deep water, wave-exposed habitats, and the distance from reproductive source populations, are all factors that mitigate against this risk.

Even in the event that reproduction by reservoir pests with long-lived larval stages (e.g. ~2-weeks for Mediterranean fanworm) led to larval advection directly into BGB, establishment of a self-sustaining population in suitable habitat would require sufficiently high larval densities to enable survival to the reproductive adult stage. As noted above, for broadcast spawning species with separate sexes (e.g. *Sabella*, *Styela*) there remains the additional requirement that adults would need to be close to each other for spawning to lead to fertilisation. In fact, in pest species with this type of biology, one of the strategies used for pest eradication is to reduce adult densities beneath the threshold required for reproductive success (Hopkins et al. 2011b)

4.5 FARM WASTES AND PEST ENHANCEMENT

In Section 2.2 and Appendix 2, various mechanisms were described whereby finfish farm wastes can exacerbate pest abundances and possibly even promote initial establishment. These are mechanisms that are known, or considered plausible, for salmon farms in sheltered low-flow environments. By contrast, due to the harsh physical nature of the proposed farming environment, it is highly unlikely that any of these mechanisms will be important, for reasons described in the following subsections.

4.5.1 Benthic pest enhancement

In relatively sheltered muddy environments, the non-indigenous bivalve *Theora lubrica* can thrive in areas of seabed subject to organic enrichment, such as is typical of finfish and shellfish farms (Forrest & Creese 2006; Keeley et al. 2012). This species is probably indicative of potential invasion patterns of other disturbance-tolerant pests that are not yet established in New Zealand (e.g. the MPI-designated pest Asian clam, *Potamocorbula amurensis*).

Similarly, mobile marine pests, such as the crab *Charybdis japonica*, could in theory aggregate to the food source provided by: (i) deposited biofouling material, especially that released by active defouling of farm structures, or (ii) enhanced densities of prey species, which may include bivalves like *Theora lubrica* or other infaunal or epifaunal species. The potential for such issues arising in relation to the proposal are minimised by the sandy seabed (already impoverished in terms of its biota) and the likelihood of minimal seabed enrichment or disturbance as a result of farm waste deposition (ADS 2019b).

4.5.2 Localised water column enrichment

Localised water column enrichment with nutrients or particulate organic matter provides a potential food source that could theoretically benefit and enhance certain species.

Dissolved nitrogen: In relation to finfish aquaculture development in the southern Hauraki Gulf, Kelly (2008) suggested that nutrient inputs could promote the kelp *Undaria*. However, the proposed farms are expected to have a minimal impact on water column dissolved nitrogen (Lim et al. 2019a). Furthermore, such enrichment effects if they occurred in relation to the development, would be confined to farm structures, as *Undaria* is not capable of inhabiting the seabed beneath. However, based on experience elsewhere, locally elevated nutrient levels are unlikely to be significant for attached macroalgae. A salmon aquaculture risk assessment in the Marlborough Sounds (Forrest 2011) noted that *Undaria* was not visibly more abundant or luxuriant in close proximity to existing salmon farms or other point source nutrient inputs. Rather, invasiveness in both artificial and natural habitats varies considerably across small spatial scales (*e.g.* across tens of metres) as well as inter-annually, irrespective of anthropogenic influences (Forrest & Taylor 2002).

Particulate organic matter: Localised water column enrichment with particulate organic matter provides a potential food source that could benefit biofouling or epibenthic filter feeding invertebrates, such as *Styela* and *Sabella*. It is unknown whether a benefit to individuals, if it occurred, would translate to enhanced population densities. In any case, such effects in the case of this proposal would be localised to the structures, and would likely be over-ridden by factors discussed above that are expected to limit the proliferation of pest species on structures in the high energy environment of the proposal area.

In summary, therefore, enhancement effects from farm wastes are likely to be of negligible significance in terms of marine pest establishment in the case of the project proposal. Furthermore, the capacity for such effects already arises due to pre-existing activities. Even if such effects occurred, it is unlikely that salmon farm wastes would modify the environment in a way that provided an avenue for the initial establishment of pest species.

5. SYNTHESIS OF EFFECTS AND OPTIONS FOR MANAGEMENT

5.1 SYNTHESIS

The key issues and conclusions described in the assessment of effects, as well a subjective rating of the significance of these effects and the generic needs for management, are summarised in Table 3. These issues reflect the main processes by which salmon aquaculture could give rise to marine pest risk, which were summarised in Fig. 4.

The Table 3 summary reflects that the most significant marine pest risk associated with the project 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 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 main issues addressed in this report and summarised in Table 3 relate to potential effects due to farm structures creating reservoirs for marine pests, and farm wastes 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 context of this project.

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, temperature ranges at the lower end of known tolerance for some species, and relatively featureless soft-sediment habitats in the farming environs.

5.2 MANAGEMENT NEEDS AND OBJECTIVES

Given that marine pests are a particular threat to aquaculture, Sanford has a strong economic incentive to prevent introductions of risk species, and to ensure early detection and effective management of established pests to levels that minimise adverse effects on their operations. Such efforts have the dual benefit of also reducing risk to the wider environment.

A biosecurity management plan (BMP) provides a mechanism for managing known risks to a negligible level, and dealing with uncertainties that arise. For example, the risk profile to and from Sanford, and from other exacerbators of regional risk, will change over time as species distributions change within New Zealand and new pests arrive from overseas. The key elements and objectives of a BMP need to include:

1. Minimising the likelihood of introduction to the farming areas of potentially harmful organisms.
2. Ensuring early on-farm detection of potentially harmful organisms.
3. Ensuring effective on-farm control and containment of potentially harmful organisms.
4. Ensuring effectiveness of risk management with appropriate training and management systems (e.g. pest identification & response procedures).

The latter builds on systems already in place for BGB farming operations, with the discussion below focusing on the key technical considerations relating to objectives 1-3. The purpose is to outline the main BMP elements, with some matters of detail not able to be comprehensively addressed until operational details are finalised (i.e. subject to consent being granted).

Note that the BMP could either sit alongside the Fish Health Management Plan that Sanford will develop (as an extension of the FHMP for their BGB operation) or be incorporated into it. The latter approach has merit given that the disease management measures applied to 'topside' pathways (i.e. non-submerged surfaces) would also be effective against marine pests (see Section 4.3.1).

It is also noted that the *Bonamia* CAN (see Section 3.4) has provisions for managing risk pathways, but

Table 3. Summary of potential effects resulting from the project 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

the CAN may have a limited duration and is not specific to marine pests. As such, the text below refers to the BMP as the primary document for risk management, while recognising that the requirements outlined need to be consistent with (i.e. at least as stringent as) any specific measures associated with the CAN while it remains in place.

5.3 PATHWAY MANAGEMENT

5.3.1 General

Comprehensively managing risk pathways is the best strategy to address uncertainty and limit the potential for 'downstream' problems to arise. Management that addresses the entire pathway (e.g. by minimising hull fouling) as well as targeting specific pests, provides the most effective way to address potential as-yet-unrecognised pest species. For the industry, it also provides a mechanism to minimise risk from the suite of species that are regionally or nationally significant to the industry but have no officially recognised status as pest organisms (Forrest et al. 2014).

5.3.2 Vessel hull fouling management

The measures proposed below are based on a minimum antifouling requirement and a 'clean hull' standard to meet Southland's Regional Coastal Plan (RCP) Objective 7.3.8.2.2 (Minimise risk of bioinvasion), as well as specific measures to address SRPMP pests.

Antifouling

Vessels should have an antifouling system applied in accordance with the manufacturer's instructions. The antifouling system should be within the in-service period planned at the time of application. Guidance on effective antifouling can be found in the Australia and New Zealand 'Anti-fouling and In-water Cleaning Guidelines' (DOE-MPI 2015).

Hull biofouling management

Vessels within the control of Sanford that are visiting the farming areas will be subject to the following hull management practices:

1. For vessels visiting the farming areas that have operated within territorial waters outside the Southland region since last antifouling, the hull should be cleaned out of water (by water-blasting) within 30 days of arrival. As an acceptable alternative to cleaning, evidence (e.g. from dive inspection) may be provided that hull biofouling does not exceed the thresholds outlined in Appendix 6 AND is visibly free of notifiable or unwanted species, SRPMP pests, or any other species otherwise designated by the Ministry for Primary Industries as marine pests

2. For vessels visiting the farming areas that have operated only within the Southland region or offshore (outside territorial waters) since last antifouling, the extent of biofouling should not exceed 5% of the combined surface area of main hull and niche areas AND should be visibly free of notifiable or unwanted species, SRPMP pests, or any other species otherwise designated by the Ministry for Primary Industries as marine pests. Hull inspection at least annually should be undertaken to determine compliance with this requirement. Note that the 5% threshold is consistent with that adopted by some councils for recreational boats.

3. As an alternative to the measures outlined in 2 for regionally-operating vessels, the nature and extent of biofouling would be considered acceptable if assessment by a suitably qualified person demonstrated that the level of risk posed by vessel movement was equivalent to, or less than, that posed by the threshold described.

4. All Sanford-operated vessels should maintain a Biofouling Record Book as outlined by the International Maritime Organisation, to facilitate record keeping relating to vessel biofouling management (i.e. antifouling certificates, hull inspection and cleaning reports, etc).

5. Where hull cleaning is required, cleaning out-of-water by methods such as water blasting is preferred to in-water methods, although spot removal of biofouling may be acceptable is some circumstances. Under RCP rule 7.3.8.2.3, hull cleaning within the coastal marine area is a permitted activity, provided there are no discharges of toxicants and no release of viable unwanted or pest organisms.

5.3.3 Measures for equipment, on-board seawater and other mechanisms

As previously noted, the measures put in place for disease risk management are also expected to be effective against actual or potential marine pests associated with 'topside' mechanisms of vessels and equipment. Notwithstanding this situation, the following general requirements for marine pest risk minimisation should be considered for a BMP and integrated with disease management measures:

i. Infrastructure needed for farm development and any ongoing maintenance should either be new (preferably) and not exposed to source-region risk, or treated so as to ensure it is pest-free before it is transported to the farming areas.
ii. All marine gear and equipment associated with vessels should be visibly clean, free of fouling, free of sediment and preferably dry.
iii. Any on-board seawater discharged into the farming areas should be visibly clean and free of sediment, and treated as appropriate (e.g. filtration, UV sterilisation) to remove viable life-stages of marine pests (actual treatment requirements to be determined once operational details finalised).
iv. Other than the feed barge attached to each of the farms, anchoring of vessels within the environs of farming areas should be avoided or minimised to the extent feasible, except where needed in an emergency situation. If anchoring, is otherwise necessary, anchors and ground tackle should be clean of sediment and debris to the extent feasible.

5.4 ON-FARM MANAGEMENT

On-farm management measures to reduce risk to salmon farming operations and the wider environment should include:

- Surveillance for early detection of potential pests.
- Implementation of measures to eliminate or contain new incursions, or for ongoing control.

Active surveillance for potentially harmful organisms should be an embedded part of day-to-day farming operations, noting that this is already standard practice on all Sanford marine farms. Surveillance should focus on the designated pests described in this report, as well as any other species of concern to the industry or anything unusual. Surveillance should also aim for early detection of unrecognised organisms that show invasive behaviour (e.g. unknown or unfamiliar organisms that become abundant). On-farm surveillance provides support for broader marine pest surveillance that is funded by MPI and undertaken 6-monthy in New Zealand's main ports (including Bluff Harbour).

In terms of managing pest species on-farm, eradication may not be feasible, but some level of containment and control may be achievable. Containment approaches combine pathway management (e.g. management of vessels moving away from the farming areas) and on-farm pest control. As previously noted, manual fouling biomass control (e.g. by scraping & water blasting) will be necessary for operational reasons, especially as Sanford have chosen (for environmental reasons) not to use copper-based antifouling coatings. Based on a Norwegian study, maintaining growing nets largely free of fouling would alone address ~75% of the surface area of farm infrastructure (Bloecher et al. 2015). The specific frequency of defouling will be determined by the rate of biofouling development.

Within the aquaculture industry, it is considered an acceptable practice to allow defouled material to fall to the seabed, as it contains no toxicants; in any event, there are no practical methods available for waste capture. However, Environment Southland has specific rules in their RCP relating to in-water defouling. In the case of Sanford BGB consents, conditions require structures to be maintained free of unwanted organisms and pests. Furthermore, any removed unwanted organism or pest is required to be disposed of at an authorised land disposal site.

The specific requirements for surveillance and on-farm management, including aspects such as training in pest identification, and reporting of finds, can be outlined as part of the development of the BMP.

5.5 BROADER CONSIDERATIONS

One of the additional matters that will need to be considered during BMP development, for both pests and disease, will be the extent to which each of the farming areas can be effectively managed as an 'independent epidemiological unit', so that the emergence of a pest or disease in one farming area does not inadvertently spread to other areas, by industry pathways or natural dispersal processes. In such respects, a further way to deal with uncertainty and help safeguard against the potential for significant unforeseeable events would be to develop the farming areas in stages, within an adaptive management framework that included appropriate monitoring, related investigations as necessary, and criteria for up-scaling to successive stages.

Finally, it is important to reiterate that a considerable marine pest risk to the Southland region exists irrespective of the project application. In this respect, the fit-for-purpose BMP measures proposed are intended to strike a balance between risk reduction and practicality. If more stringent consent requirements or conditions are considered appropriate for the current proposal, then equivalent conditions should be required on other activities to mitigate risks in an equitable manner and avoid creating any unfair burden on Sanford, its contractors or Environment Southland.

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APPENDIX 1. LIFE-STAGES OF MARINE PESTS POTENTIALLY TRANSPORTED WITH HUMAN ACTIVITIES OR LEADING TO NATURAL DISPERSAL AND SPREAD

Planktonic dispersal stages: Most marine algae and benthic invertebrates have microscopic reproductive life-stages (e.g. algal spores, invertebrate larvae) that can drift as plankton with water currents, or be carried in water associated with vessels and other anthropogenic vectors (e.g. ballast and bilge water). In the case of human-mediated pathways, the risk depends in part on the competency period of the planktonic stage in relation to transport time from the source region to destination.

For some recognised risk species, competency periods are relatively short (e.g. a few hours to a few days), meaning that human activities can greatly exacerbate the extent and rate of spread; e.g. Asian kelp *Undaria pinnatifida*, and sea squirts including *Pyura doppelgangera*, *Styela clava* and *Didemnum vexillum* (Wong et al. 2011; Fletcher et al. 2013b; Fletcher 2014).

By contrast, a number of MPI-designated pests have planktonic competencies of several weeks to a few months, giving them a capacity for long-distance natural in addition to human-mediated spread. Examples include the fanworm *Sabella spallanzanii* (Currie et al. 2000), the Northern Pacific seastar, *Asterias amurensis* (Byrne et al. 1997) and the European shore crab, *Carcinus maenas* (Audet et al. 2008).

Note that some organisms are planktonic for their entire life cycle (termed 'holoplankton'). Among the problematic phytoplankton are harmful algal bloom species (and their benthic cyst stages), which are addressed in a separate AEE report accompanying this application. Among the zooplankton, few organisms are recognised as risk species, probably the most well-known internationally being the Mediterranean comb jelly *Mnemiopsis leidyi* (which occurs on the National Geographic's '100 least wanted' list of invasive species).

Fragments of colonial organisms: Fragmentation is a key mechanism for dispersal and establishment in some species, hence entrainment of fragments (e.g. in water, on deck spaces) has the potential to transfer organisms among locations. Establishment by fragments has been documented for colonial species including the sea squirts *Didemnum vexillum* and various bryozoans, although fragments need to be several millimeters in size to effectively reattach (Hopkins et al. 2011a). In some cases, fragments of solitary organisms can also regrow individuals, such as reported for the Mediterranean fanworm, *Sabella spallanzanii*, under laboratory conditions (Licciano et al. 2012) and for the northern Pacific seastar, *Asterias amurensis* (MPSC 2015).

Intact adult organisms: In certain circumstances, intact adult organisms can be transported with human activities. One of the increasingly recognised mechanisms associated with large vessels is the transport of adult organisms in 'sea chests', which are hydrodynamically protected recesses in the hull containing the pipework used for pumping water onboard (Coutts & Dodgshun 2007). Mussel seed-stock transfers have also been implicated in the domestic spread of pests such as *Undaria*, *Styela* and *Sabella*. Such organisms may not be removed from the shell by the cleaning (declumping and washing) processes used at mussel harvest, meaning they are transferred with mussel movements to new locations.

APPENDIX 2. ROLE OF AQUACULTURE IN THE ESTABLISHMENT AND SPREAD OF MARINE PESTS

The ways that aquaculture in New Zealand can become an exacerbator of marine pest risk were conceptualised in Fig. 4 of the main report, with further information and examples provided below.

Risk pathways

Risk pathways associated with most aquaculture activities are varied, and can contribute to the spread of pests both within and among growing regions. Specialist vessels may move within and among regions for farm installation, maintenance, and operational activities such as stocking or harvest. 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 debris on deck areas, sediments (e.g. on anchors), and retained water such as bilge water (Acosta & Forrest 2009; Darbyson et al. 2009; Sinner et al. 2009; Fletcher et al. 2017); however, for most of these additional mechanisms evidence is lacking as to their significance. Depending on the mechanism, pests may be transported in the form of intact adult organisms, viable fragments (for certain species) or microscopic life-stages (e.g. see Appendix 1).

Of particular significance historically in New Zealand have been industry transfers of farm floats (mussel farms), pontoons (salmon farms) and ropes among farms and growing areas and, in the case of shellfish aquaculture, the transfer of pest-infected (e.g. fouled) seed-stock (Forrest & Blakemore 2006; Forrest & Fletcher 2015). Even where transfers (e.g. of gear) are made long distances out of the water (e.g. on trucks or vessel decks), research has shown that many organisms or life-stages can survive the desiccation stress, especially where high humidity conditions are maintained such as in coils of rope (Schaffelke & Deane 2005; Forrest & Blakemore 2006; Hopkins et al. 2016). Moreover, as such transfers typically involve long-term deployments, pests surviving the out-of-water transport phase typically have sufficient time to grow and reproduce in their new location, provided environmental conditions are suitable.

Ineffective management of risk pathways may therefore lead to the introduction of pest species to and among marine farms. This occurrence is of most significance in situations where the pest is not established regionally, and has little or no capacity to establish in marine farming locations by natural dispersal mechanisms. Conversely, where a particular pest is already established locally and is likely to colonise new marine farm structures, targeted pathway management for that particular pest would be largely futile.

Farm structures and environs as pest habitats and reservoirs for spread

Studies internationally and in New Zealand have shown that marine assemblages on artificial structures are often dominated by NIS (Glasby et al. 2007; Ruiz et al. 2009; Woods et al. 2012). Relative to the seabed, off-bottom or floating structures such as finfish farms provide extensive and physically complex structures on which pest species can become abundant, in particular sessile (attached) biofouling species and associated mobile species; e.g. crabs (Forrest et al. 2014). Among the most visually conspicuous and dominant species on mussel and/or salmon farms in the Marlborough Sounds and/or Firth of Thames are marine pests such as the Asian kelp, *Undaria pinnatifida*, the sea squirt *Styela clava*, the Mediterranean fanworm *Sabella spallanzanii* (Firth of Thames), or other non-indigenous species (Forrest et al. 2014; Watts et al. 2015). Dislodgement of species to the seabed, for example, by active farm defouling, has the potential to contribute to seabed establishment (Floerl et al. 2016).

In addition to physical habitat provided by farm structures, farm wastes have the potential to alter the environment in favour of pest species. One of the localised effects of finfish aquaculture is the development of a strong organic enrichment gradient and associated faunal changes in sediments beneath and adjacent to pens (Forrest et al. 2007). These types of environmental disturbances are recognised factors that can contribute to the invasion or proliferation of NIS (Piola & Johnston 2008).

For example, the nonindigenous soft-sediment bivalve *Theora lubrica* has been described at greatly enhanced abundances at intermediate levels of seabed organic enrichment or disturbance from finfish and shellfish farms (Forrest & Creese 2006; Keeley et al. 2012).

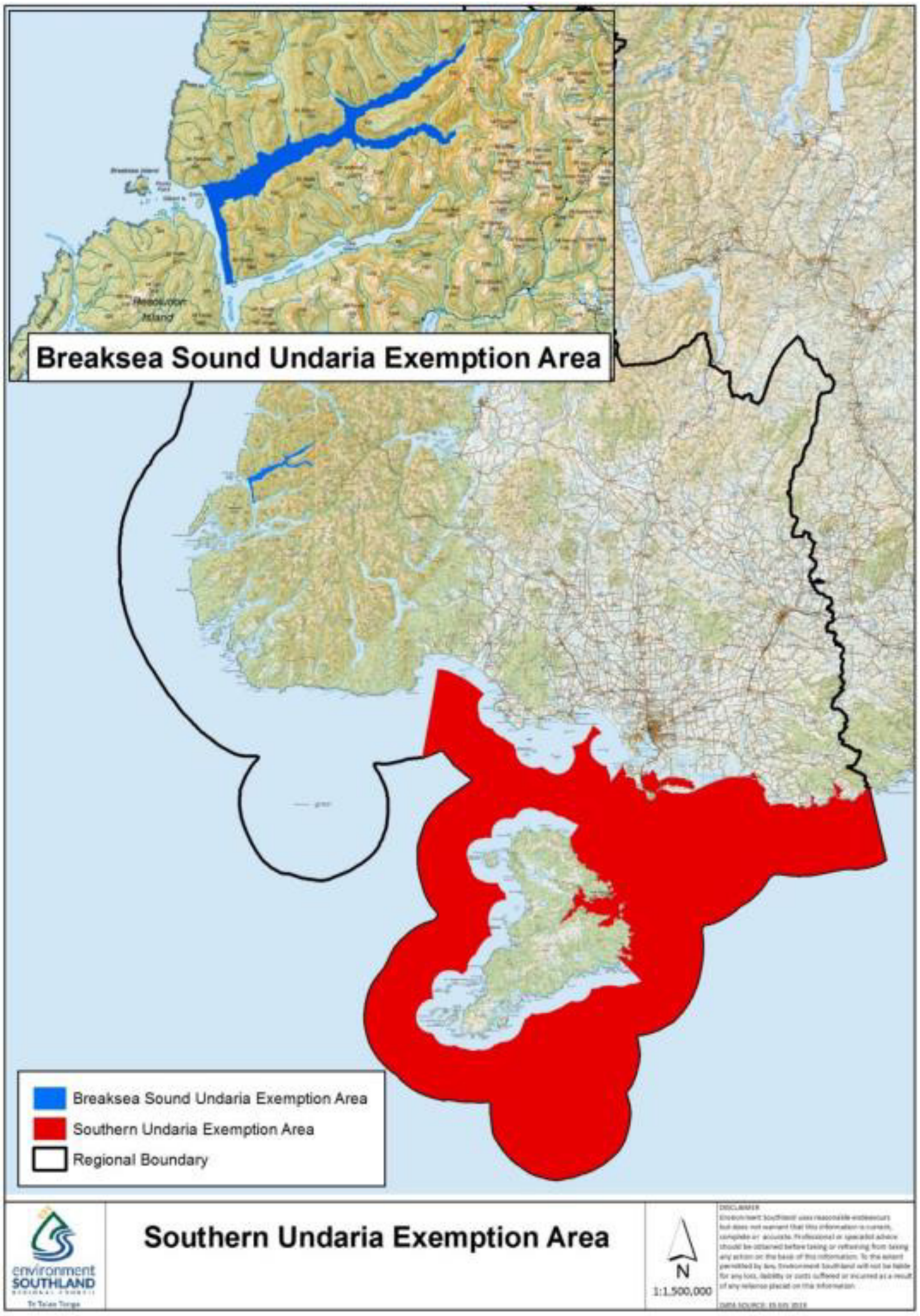
Other potential mechanisms for pest enhancement also exist, but are poorly understood. For instance, another way that the seabed may be modified is from deposition of biofouling from farm structures. As well as being a potential mechanism for the spread of pests from farm structures to natural habitats, this process may lead to the aggregation and localised enhancement of species already established. Water column enrichment with particulate organic matter or dissolved nutrients also has the potential to enhance locally established populations of pests (e.g. of invasive macroalgae such as the kelp *Undaria*).

The development of high densities of pests on farm structures or the local environment has the potential to exacerbate further spread into the wider system. A finfish farm with an established marine pest population could pose a local biosecurity risk if the pest extended its range into the surrounding bay-scale environment by mechanisms such as natural dispersal. The regional environment could be affected in the longer term by the incremental spread from locally established populations, possibly exacerbated by the 'stepping-stone' spread of pests among adjacent marine farms or other artificial structures. However, the rate of spread at regional scales (or beyond) is likely to be accelerated where there is secondary infection of vessels and other anthropogenic vectors, both related and unrelated to aquaculture activities.

Forrest and Hopkins (2013) describe case studies of managed pests in New Zealand for which many of the above mechanisms of spread were described. For example, the first documented spread of the sea squirt *Didemnum vexillum* beyond a single bay in the Marlborough Sounds resulted from the long distance in-water tow of a fish farm pontoon, which was infected with the microscopic life-stages of *Didemnum*. In its new location the sea squirt subsequently proliferated, and spread by natural dispersal to an adjacent mussel farm, and thereafter to other mussel farms in the same bay (Coutts & Forrest 2007). In at least one location the same species caused significant impacts on finfish culture operations, by occluding farm nets and impeding water flow through the farm. In such situations, dissolved oxygen can be depleted and flushing of finfish waste products reduced, leading to on fish stocks that may make them susceptible to disease.

APPENDIX 3. AREAS EXEMPT FROM SOUTHLAND REGIONAL PEST MANAGEMENT PLAN RULES RELATING TO THE ASIAN KELP *UNDARIA*

Vessels operating exclusively within the two designated areas are exempt from SRPMP (2019) Rule 13 that requires they be free of *Undaria*. The 'Southern Undaria Exemption Area' appears to encompass part of the project application area.



APPENDIX 4. CONTROLS FOR SANFORD VESSELS AND MUSSEL ASSOCIATED WITH A CONTROLLED AREA NOTICE FOR BONAMIA RISK MANAGEMENT

Date: **Thursday, 27 February 2020** **Permit No: Bonamia 2017 0289**

Applicant	Sanford Ltd
Vessel/Vehicle	San Hauraki, Marine Countess, Foveaux Freighter/Courier
Consignment	Green Lipped Mussel samples

Please find enclosed a Movement Permit as requested in relation to Section 134 of the Biosecurity Act 1993 and Schedule 4 Controlled Area Notice BRC 2017 Biosecurity Response Movement Control Restrictions for *Bonamia ostreae*.

You must comply with the conditions for this movement as set out in the permit when moving into and out the Stewart Island Zone Controlled Area Notice. Conditions apply to each individual movement within the specified time period to which this multiple movement permit applies

Other information enclosed includes:

- A copy of the Controlled Area Notice.
- Information which outlines the penalties for non-compliance.

If you have any enquiries, please contact our free phone on 0800 80 99 66 or email bonamiapermit@mpi.govt.nz

MULTIPLE MOVEMENT PERMIT

SECTION 134 OF THE BIOSECURITY ACT 1993 AND SCHEDULE 4 CONTROLLED AREA NOTICE BRC 2017

Movement details:

Movement Details	
Vessels	**Name:** San Hauraki **Reg Number:** MSA 101740 **Colour:** Blue **Name:** Marine Countess **Reg Number:** MSA 101856 **Colour:** Blue & Silver **Name:** Foveaux Freighter **Reg Number:** MSA 129625 **Colour:** Silver
Consignment	Green Lipped Mussels (*perna canaliculus)* Approximately 30 Green Lipped Mussels per consignment
Movement	Vessel: 1. Travel from No 1 Berth Bluff port located within the Protection Zone of the BRC 2017 Controlled Area Notice to Big Glory Bay, Stewart Island located within the Stewart Island Zone of BRC 2017 Controlled Area Notice. 2. Return back to No 1 Berth Bluff port located within the Protection Zone of the BRC 2017 Controlled Area Notice Consignment: 1. Samples of Green Lipped mussels collected from Big Glory Bay

APPENDIX 4 (CONT.)

	Stewart Island located within the Stewart Island Zone of the BRC 2017 Controlled Area being moved out of the Stewart Island Zone to Number 1 Berth Bluff port which is located within the Protection Zone. 2. Samples are then dispatched by courier to Cawthron Institute 98 Halifax Street East Nelson which is located within the Contained Zone of the BRC 2017 Controlled Area Notice
Conditions	
Conditions:	**1.** The vessels, hull and niche areas must be clean/clear of macro fouling and evidence of continual bio-fouling management practices should be provided. The vessel must be cleaned if fouling is present. **2.** The vessels must have anchor, anchor lockers, chains etc. that are free of sediment. **3.** No ballast should be taken up from within the Stewart Island Zone of the BRC 2017 Controlled Area **4.** A copy of this movement permit and the evidence of cleaning of hull and treatment of niche areas must accompany each movement and made available upon request by enforcement/compliance officers. **5.** The permit holder must report any incident that may compromise the integrity of the movement. This includes, but is not limited to accidents. **6.** The permit holder must retain a record confirming that the permit conditions have been performed for and in relation to the movement during the movement period. **7.** The vessels are permitted to transport Green Lipped Mussels for sampling/testing purposes sourced from Big Glory Bay Stewart Island located within the Stewart Island Zone of BRC 2017 Controlled Area Notice to No 1 Berth Bluff port which is located within the Protection Zone of the BRC 2017 Controlled Area Notice **8.** Green Lipped Mussels must be mechanically de-clumped or cleaned, and pressure rinsed with freshwater (or saltwater only if fresh is not available) at the collection site. **9.** Samples of Green Lipped Mussels must be double bagged and secured in a container that can be covered/secured. These must be stored securely during transportation. In addition, all containers must be clearly labelled or have attached: a. Details of the contents and; b. Identification indicating the contents relate to the carried permit. **10.** On land or sea, in-contact equipment (with the exception of spat ropes and spat on substrate) and containers used for harvest or transport must be treated with a freshwater pressure wash (or saltwater only if fresh is not available). This must be performed as soon as practicable after any movement *or before* being used for further shellfish movements **11.** If in-contact waste material (dead stock, bio-fouling and packaging) is not disposed of at collection site, it must be transported in contained, closed containers and disposed of on-land at a point above the highest tide as soon as practicable after any movement. **12.** Report each date and time of movement and destination(s) within the

APPENDIX 4 (CONT.)

	Contained Area to bonamiapermit@mpi.govt.nz within 48 hours after movement completed **13.** Permit holders must be aware that permits may be changed based on surveillance or audit outcomes
Expiry Date:	Monday 31August 2020

Pursuant to Section 134(1)(b) of the Biosecurity Act 1993, permission is granted for the above mentioned movement to be undertaken in accordance with any conditions specified. This notice remains in force for the time specified or until written notice of revocation is given.

Inspector or authorised person:	**Trevor Charles Kapene**	Signature

Information

This measure has been imposed to restrict the spread of a pest or unwanted organism, namely *Bonamia ostreae*. Failure to comply with the conditions in this permit is an offence under section 154N(8) of the Act. This carries a penalty under section 157(4) of the Act, in the case of an individual, of imprisonment for a term not exceeding 3 months, a fine not exceeding $50,000, or both and in the case of a corporation, to a fine not exceeding $100,000.

APPENDIX 5. SUMMARY OF VESSEL ACTIVITY IN AND AROUND BIG GLORY BAY (source: Table 1 from evidence of Eriksson 2019)

Vessels	Vessel movements	Description of work	Total trips
Vessels associated with mussel farms: Sanford x 2	6 days each week; multiple movements around and across BGB. Sanford vessel **Mystic** can either anchor in BGB or travel out to Golden Bay overnight. The vessel **Erin** remains within BGB, unless going to Bluff for survey.	Seeding, grading, harvesting, mussel line maintenance, discrete operations not connected to the salmon farm	Two vessels x 5d/week for 12 months of year into and around BGB between mussel farms
Vessels associated with Sanford salmon farm: • San Hauraki • San Braz • 3 farm boats • 1 dive boat • Occasionally two charter vessels working on farm • As needed: Foveaux Freighter	**San Hauraki:** 5 x per week into BGB and then between salmon farms spending up to 5 hours in BGB on each trip. Has approx. 40 trips to move smolt onto the farm, sometimes making two trips a day. **San Braz:** usually 5 days a week into BGB and then multiple trips between farms – normally used Sun – Thu, with Friday and Saturday covered by water taxi. Over spring, San Braz is in BGB to help with grading (Aug to Dec).	**San Hauraki** delivers feed and other supplies to all salmon farms, and leaves with salmon and mussel harvested product. **San Braz** delivers shift staff to work, and is also used for moving staff and barges between farms, ie scrub barge, harvest barge, oxygen barge, fish transporter cage, grading barge	Two vessels making multiple trips 5 days a week including in an out of BGB Three vessels making multiple trips (6-10) around BGB 7 days a week, year round – these reside in BGB: One dive boat: Sun to Thu, multiple movements between 3 farms and mussel sites.
Other mussel farm business vessels	At least 5 vessels travelling back and forth daily from Oban	Seeding, grading, harvesting, plus one barge that is permanently moored in BGB	Five vessels x 5 days, year round working farms

Vessels	Vessel movements	Description of work	Total trips
Water taxi	Daily – up to 8 return trips (16 times into BGB) a week coming alongside Kiwa barge (grower farm)	Used on weekend instead of San Braz to transport staff to farm; otherwise used to bring out contractors and visitors etc	Every week year round
Charter vessels; i.e. tourists	Real Journeys – in season sometimes 3-4 times a week in BGB, going around farm sites and up against the Kiwa (salmon grower farm). Aurora, Wildfire and occasional Bluff charters – come into BGB to view wildlife and show people the farms – about 10 times a year	Tourists are mainly in summer months (October to May)	One vessel 3 times a week especially in summer months, plus 10 charter trips mainly in summer
University of Otago	Twice a year – Polaris II	One in summer and one in winter	Two trips with students
Private boats, hunters and fishers	Occasionally – maybe 15 a year	Travelling to head of BGB, or into BGB to sightsee or fish	Fifteen per year
Cruise ships	Seven last summer into Patterson Inlet	Occasionally come into BGB on small charters or use their own life boats	Unknown

APPENDIX 6. RECOMMENDED HULL BIOFOULING THRESHOLDS

For vessels arriving from territorial waters outside the Southland region. These thresholds are based on DOC (2017) Regional Coastal Plan standards (for the Kermadec and Sub-Antarctic Islands) and MPI's CRMS (2018) border standard for short-stay vessels.

Hull area (see notes)	Allowable biofouling
Main hull	Algal growth occurring as: • no more than 4 mm in length; and • continuous strips and/or patches of no more than 50 mm in width. Incidental (maximum of 1%) coverage of one organism type of either tubeworms, bryozoans or barnacles, occurring as: • isolated individuals or small clusters that have no algal overgrowth ; and • a single species, or what appears to be the same species.
Wind and water line	Green algae growth of unrestricted cover and no more than 50 mm in frond, filament or beard length; Brown and red algal growth of no more than 4 mm in length; Incidental (maximum of 1%) coverage of one organism type of either tubeworms, bryozoans or barnacles, occurring as: • isolated individuals or small clusters ; and • a single species, or what appears to be the same species.
Niche areas	Algal growth occurring as: • no more than 4 mm in length; and • continuous strips and/or patches of no more than 50 mm in width. Scattered (maximum of 5%) coverage of one organism type of either tubeworms, bryozoans or barnacles, occurring as: • widely spaced individuals and/or infrequent, patchy clusters that have no algal overgrowth; and • a single species, or what appears to be the same species; and Incidental (maximum of 1%) coverage of a second organism type of either tubeworms, bryozoans or barnacles, occurring as: • isolated individuals or small clusters that have no algal overgrowth; and • a single species, or what appears to be the same species.

Notes:

1. Main hull. The immersed surfaces of a vessel excluding niche areas and wind/water line.

2. Wind and water line. The area of the hull that is subject to alternating immersion due to a vessel's movement or loading conditions (also known in shipping as the boot-top).

3. Niche areas. Areas on a vessel hull that are more susceptible to biofouling due to different hydrodynamic forces, susceptibility to coating system wear or damage, or being inadequately, or not, painted, e.g. sea chests, bow thrusters, propeller shafts, inlet gratings, rudders, keels, trim tabs, dry-dock support strips.