Appendix U Marine biosecurity assessment of effects

Ngāi Tahu Seafood Resources Limited

Hananui Aquaculture Project

Marine Biosecurity Assessment of Effects

Evidence of Barrie Forrest regarding Hananui Aquaculture Project: Marine Biosecurity Assessment of Effects, Biosecurity Management Plan, and Proposed Conditions

Barrie Malcolm Forrest
6 November 2025

Introduction

My name is Barrie Malcolm Forrest.

My role in relation to the Hananui Aquaculture Project ("**HAP**") has been to provide expert evidence in relation to marine biosecurity. I was the lead author of the *Marine Biosecurity Assessment of Effects* and *Biosecurity Management Plan* which are provided within **Appendix U** and **Appendix V** of the application.

This evidence has been prepared to accompany the application by Ngāi Tahu Seafood Resources Limited ("**NTS**") for approvals required for the HAP under the Fast-track Approvals Act 2024 ("**FTAA**"). It has been prepared on the understanding that the process for determining applications under the FTAA does not require a hearing to be held, and accordingly the purpose of this evidence is to confirm that, relative to my area of expertise, the Marine Biosecurity Assessment of Effects and Biosecurity Management Plan provide an appropriate description of the relevant environment, the proposed activities comprising the effects of the HAP on that environment, and the way those effects are proposed to be managed.

My findings are set out in full in the following:

- Forrest BM, Johnston C. 2025. Hananui Aquaculture Project: Marine Biosecurity Assessment of Effects. Salt Ecology Report 166, September 2025. 40p. plus Appendix 1.
- Biosecurity Management Plan: Hananui Aquaculture Project, November 6, 2025 (final draft).

which are included within **Appendix U** and **Appendix V** of the application.

While this application is not being considered by the Environment Court, I confirm that I have read the Code of Conduct for expert witnesses contained in the Environment Court of New Zealand Practice Note 2023 and that I have complied with it when preparing this evidence. Other than when I state I am relying on the advice of another person, this evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Qualifications and Experience

I have been a Senior Marine Scientist and Principal at Salt Ecology since 2018, and prior to that (1994-2018) was a Senior Scientist at Cawthron Institute, which included a role as Marine Biosecurity Team Leader.

I graduated from Victoria University of Wellington in 2007 with a PhD in Marine Biology. I also have a Master of Science with first class honours in Environmental Science and Zoology (University of Auckland, 2001), and a Bachelor of Science in Zoology (University of Canterbury, 1994).

I have a background in benthic ecology and biofouling, and have specialised in the field of marine biosecurity since the late 1990s. Prior to starting full-time private consultancy in 2018, my 25-year career at Cawthron Institute included undertaking research and consultancy regarding biosecurity risks from potentially harmful marine organisms and their transport pathways (e.g. vessel movements), developing tools and approaches for risk mitigation, and managing large research programmes relating to marine biosecurity, primarily with an aquaculture industry focus.

I have authored or co-authored more than 50 peer-reviewed publications in international journals or books, many concerning marine biosecurity, and more than 300 consultancy reports regarding biosecurity, benthic impacts, environmental monitoring, and broader environmental issues.

My experience includes many biosecurity expert advisory roles relating to: present and proposed marine finfish aquaculture developments around New Zealand; a role as science adviser to the Top of the South Marine Biosecurity Partnership; a role with the Top of the North Marine Biosecurity Partnership on development of a 'Clean Vessel Plan'; and participation in national, regional and sector-based Technical Advisory Groups for managing most of the high-profile marine pests in New Zealand.

In providing this evidence in relation to marine biosecurity, I have considered the following matters as relevant to that topic:

- The project description provided by NTS as set out in section 6 of the application;
- The description of the existing environment, the effects of the HAP on that environment and their significance, and the proposed management and mitigation measures to manage those effects all as set out in the assessment of environmental effects accompanying the application;
- The technical assessments of Cawthron Institute on the benthic assessment and depositional modelling (*Assessment of seabed effects associated with farming salmon offshore of northern Stewart Island / Rakiura, Cawthron*); and
- A wide range of data sources including: previous Hananui biosecurity (pest and disease) assessments that were prepared for an Expert Consenting Panel under the COVID-19 Recovery (Fast-Track Consenting) Act in 2023; scientific studies describing the biology of marine pests and diseases, their impacts, processes of spread, and management tools; data on the movements of vessels and other anthropogenic pathways that lead to the spread of pests and diseases; current or developing regional and national biosecurity management approaches; Aquaculture New Zealand biosecurity standards; information requests to government agencies (Environment Southland and the Ministry for Primary Industries, MPI) on specific matters; and other sources such as the Southport website and marinetraffic.com (vessels movements) and the MPI Marine Biosecurity Porthole website (national distribution data for potentially harmful organisms).

Confirmation of Contents of Report and Proposed Conditions

I confirm that in my opinion the *Marine Biosecurity Assessment of Effects* and *Biosecurity Management Plan* contain an accurate and appropriate description of the environment, the actual and potential effects of the HAP, and the recommended actions to manage those effects within my area of expertise.

I confirm that in my opinion the contents of the *Marine Biosecurity Assessment of Effects* and *Biosecurity Management Plan* may be relied on in making a decision on the approvals sought for the HAP and confirm that provided effects within my area of expertise are managed as proposed in the application those effects will not be unacceptable and will be managed to a standard that I consider meets good practice.

I confirm that I have reviewed the conditions that NTS proposes for the approvals being sought as they relate to my area of expertise. I confirm that in my opinion, those proposed conditions are appropriate.

[redacted]

Barrie Forrest

November 6, 2025

Ngāi Tahu Seafood Resources Limited

Hananui Aquaculture Project

Animal Biosecurity – Risk, Effects and Management

Evidence of DR COLIN JOHNSTON regarding the Hananui Marine Biosecurity AEE, the Biosecurity Management Plan and Proposed Conditions

Dr Colin Johnston
11-9-2025

Introduction

My name is Dr Colin Johnston.

My role in relation to the Hananui Aquaculture Project ("**HAP**") has been to provide expert evidence in relation to aquatic biosecurity risk and biosecurity management from the perspective of aquatic animal pathogens. I wrote the relevant sections of the Hananui Marine Biosecurity AEE report, including the aquatic pathogen risk assessment found as Appendix 1 of that report, and the Biosecurity Management Plan which are provided within **Appendix U** and **Appendix V** of the substantive application.

This evidence has been prepared to accompany the application by Ngāi Tahu Seafood Resources Limited ("**NTS**") for approvals required for the HAP under the Fast-track Approvals Act 2024 ("**FTAA**"). It has been prepared on the understanding that the process for determining applications under the FTAA does not require a hearing to be held, and accordingly the purpose of this evidence is to confirm that, relative to my area of expertise, the Hananui Marine Biosecurity AEE and the Biosecurity Management Plan provide an appropriate description of the relevant environment, the proposed activities comprising the effects of the HAP on that environment, and the way those effects are proposed to be managed.

My findings are set out in full in the Hananui Marine Biosecurity AEE and the Biosecurity Management Plan included within **Appendix U** and **Appendix V** of the application.

While this application is not being considered by the Environment Court, I confirm that I have read the Code of Conduct for expert witnesses contained in the Environment Court of New Zealand Practice Note 2023 and that I have complied with it when preparing this evidence. Other than when I state I am relying on the advice of another person, this evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Qualifications and Experience

I am a veterinarian, qualified for 32 years and have spent 27 years working in the sphere of aquatic animal disease and biosecurity.

I graduated from the University of Glasgow with a Bachelor of Veterinary Medicine and Surgery degree, with Honours [BVMS(Hons)], and I am a Member of the Australian and New Zealand College of Veterinary Science by examination in Aquatic Medicine [MACVSc(Aquatic Medicine)].

I am a Partner in Brightwater Partners providing aquatic diagnostics, biosecurity advice and risk analysis to private aquaculture companies, research organisations and government departments in New Zealand and overseas.

I am also employed as the Chief Technical Officer for the Tassal Group, which runs the largest individual Atlantic salmon, prawn, barramundi and seaweed farming operations in Australia, with over 31 million fish across 31 farming sites in Tasmania and Western Australia, and over 400 hectares of prawn ponds in Queensland and New South Wales. The expertise I provide in the matter of this application for farming space off Stewart Island does not represent any relationship between Tassal Group and Ngai Tahu Seafoods/Hananui.

My previous employment in the area of aquaculture, aquatic animal health and biosecurity has included:

- Technical Director, Aquaculture New Zealand with responsibility for provision of advice to industry on aquatic animal health, development of industry aquatic animal health and biosecurity standards and representation of the aquaculture industry to central and local government on issues relating to aquatic animal health and biosecurity.
- Principal Adviser, Aquatic Animal Diseases for the Ministry for Primary Industries (MPI), New Zealand with responsibility to provide advice across all aspects of policy, surveillance, risk, diagnostics and trade rules. In this role I was also the Fish Pathologist for the MPI and provided pathology expertise for the investigation of fish kills reported to the MPI.
- General Manager, Aquatic Resources, Aquaculture Directorate of the South Australian Government. My responsibilities included the management of the State aquatic animal health program, which included field investigations of fish kills and production health issues, aquaculture zone policy development, management of the aquaculture environment policy section and legislative development in the areas of aquatic animal health and aquatic biosecurity.
- Veterinary Services Manager for Marine Harvest (Scotland) Ltd., where I led a team with responsibility for the health and welfare of 40 million fish across more than 50 farm sites.

In aquatic animal health, disease and biosecurity matters, I have professionally represented:

- The State Government of South Australia at the National Aquatic Animal Health Technical Working Group (NAAH-TWG), the Aquatic Animal Health Committee (AAHC) and the Aquatic Consultative Committee on Emergency Animal Disease (AqCCEAD), all committees existing or having existed in the Federal Primary Industries Ministerial Committee structure of Australia.
- The Government of New Zealand on the Aquatic Animal Health Committee (AAHC) and the Aquatic Working Group of the Animal Health Quadrilaterals (covering Australia, Canada, New Zealand and United States of America).
- New Zealand on the mollusc diseases working group of the joint European Union, Canada, Australia and New Zealand Knowledge Based Bio Economy (KBBE) forum.

I have led groups advising changes in international aquatic animal health standards for the Aquatic Animal Health Standards Commission of the World Organisation for Animal Health (WOAH, formerly the OIE) in the following:

- Chair of the ad hoc working group on the Safety of Commodities from Aquatic Animals;
- Chair of the ad hoc working group on the Safe Treatment of Aquatic Animal Wastes and By-products;
- Chair of the ad hoc working group on Pathogen Differentiation in Aquatic Animals; and;
- Chair of the ad hoc working group on Declaration of Freedom from Disease.

I have acted as Membership Examiner for the Australian College of Veterinary Science in Aquatic Medicine and I have also acted as Head Subject Examiner for the Australian College of Veterinary Science in Aquatic Medicine.

I was appointed an Honorary Research Fellow at the University of Tasmania School of Aquaculture (2004 to 2007), and a visiting lecturer for year 2 and year 3 BSc(Aquaculture) students at Flinders University of South Australia (2003-2006).

In providing this evidence in relation to the risk from aquatic pathogens and their management through biosecurity measures, I have considered the following matters as relevant to that topic:

- The project description provided by NTS as set out in section 6 of the application;
- The description of the existing environment, the effects of the HAP on that environment and their significance, and the proposed management and mitigation measures to manage those effects all as set out in the assessment of environmental effects accompanying the application;
- The previous technical assessment of Dr Ben Diggles on aquatic pathogen risk; and
- Peer reviewed scientific journal articles, academic theses, published relevant scientific reports for government, private companies or non-governmental organisations, textbooks, presentations at scientific conferences and the author's own 27 years' experience in aquatic diseases and biosecurity.

Confirmation of Contents of Report and Proposed Conditions

I confirm that in my opinion the Hananui Marine Biosecurity AEE and the Biosecurity Management Plan contain an accurate and appropriate description of the environment, the actual and potential effects of the HAP, and the recommended actions to manage those effects within my area of expertise.

I confirm that in my opinion the contents of the Hananui Marine Biosecurity AEE and the Biosecurity Management Plan may be relied on in making a decision on the approvals sought for the HAP and confirm that provided effects within my area of expertise are managed as proposed in the application those effects will not be unacceptable and will be managed to a standard that I consider meets good practice.

I confirm that I have reviewed the conditions that NTS proposes for the approvals being sought as they relate to my area of expertise. I confirm that in my opinion, those proposed conditions are appropriate.

[redacted]

Colin Johnston

25 November 2025

SALT
ECOLOGY

Hananui Aquaculture Project: Marine Biosecurity Assessment of Effects

Prepared for

Ngāi Tahu Seafood

September 2025

Salt Ecology
Report 166

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Hananui Aquaculture Project: Marine Biosecurity Assessment of Effects

Prepared by

Barrie Forrest[1] and
Colin Johnston[2]

for

Ngāi Tahu Seafood

September 2025

[1] Salt Ecology, New Zealand

[2] Brightwater Partners, Australia

GLOSSARY

AGD	Amoebic Gill Disease
ALOP	Acceptable Level of Protection
AQNZ	Aquaculture New Zealand
BCWD	Bacterial Cold-Water Disease
BMP	Biosecurity Management Plan
CAN	Controlled Area Notice
CRMS	Craft Risk Management Standard
ES	Environment Southland
FFC	Florfenicol (antibiotic)
HSMI	Heart and skeletal muscle inflammation (reovirus)
IPNV	Infectious pancreatic necrosis (virus)
ISAV	Infectious salmon anaemia (virus)
LSPZ	Lower South Protected Zone
MPI	Ministry for Primary Industries
NTS	Ngāi Tahu Seafood
PD	Pancreas disease (alphavirus)
PAA	Peracetic acid
PPE	Personal Protective Equipment
PMPS	Potassium peroxymonosulfate
RAS	Recirculating Aquaculture Systems (RAS)
RTFS	Rainbow Trout Fry Syndrome
RLO	Rickettsia-like organism - pathogen (e.g., *Piscirickettsia*)
SRPMP	Southland Regional Pest Management Plan

ACKNOWLEDGEMENTS

We are grateful to Thomas Hildebrand (Ngāi Tahu Seafood), Frances Lojkine (Stantec) and Richard Peterson (Stantec) for support in undertaking this project, provision of background information and review of a report draft. We also thank Dan Kluza and Davide Santoro, Ministry for Primary Industries (Biosecurity New Zealand) for feedback on a draft Biosecurity Management Plan.

TABLE OF CONTENTS

FIGURES

TABLES

SUMMARY

BACKGROUND

Ngāi Tahu Seafood (NTS) propose a salmon farming development, referred to as the Hananui Aquaculture Project (hereafter Hananui), in Foveaux Strait north of Rakiura/Stewart Island. Among the assessments of ecological and other environmental effects associated with such a development, are potential marine biosecurity issues. Marine biosecurity in Aotearoa New Zealand refers to the management of risks posed by pests and pathogens (disease-agents) 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 biosecurity risks associated with the proposal, building on assessments undertaken as part of a previous consent application, and accounting for feedback from extensive consultation with stakeholders including the Ministry for Primary Industries (MPI) and Environment Southland. The report summarises the mitigation measures that will be implemented to reduce risk, which are detailed in a separate standalone Biosecurity Management Plan (BMP).

ASSESSMENT OF EFFECTS

The assessment considers the risk 'pathways' that could introduce new organisms to the region, or exacerbate the spread of those already present, as well as the farm-scale processes that could lead to the establishment and proliferation of potentially harmful organisms in the project area. A summary of the key potential effects, and their incremental significance following implementation of management measures to reduce risk, is provided in the Table on the following page. Key points from the assessment are as follows:

- The most significant risk pathways are movements of vessels, equipment and farm stock into the farming area from external domestic source regions (outside Southland). As such, planned mitigation includes implementation of management measures to reduce potential risks to a negligible level.
- The proposal will add to the within-region movements of vessels and other risk pathways, however the biosecurity significance of Hananui farm operations is inherently low due to the restricted area of operation; i.e., the farming area, Bluff Harbour, and possibly Oban, with no interaction with remote or pristine areas of Southland.
- The collective pathway mitigation measures make it highly unlikely that Hananui activities would lead to the introduction of new harmful organisms into the region, or greatly exacerbate the spread of organisms already present. Rather, it is more likely that farm vessels/equipment would be exposed to such organisms after they had become established following spread by non-Hananui pathways (for which management is limited) into connected regional hubs (especially Bluff Harbour).
- At the farm scale, the potential for proliferation and subsequent adverse effects from harmful organisms is minimised by a suite of management measures proposed in the BMP, and the isolated position of the farming area relative to regional aquaculture operations. Key related points are as follows:
    - Farm biofouling will be managed to low levels for operational reasons, and include targeted management to reduce disease risk to wild flat oysters ('Bluff oysters') from reservoir populations of bivalve hosts on the farms.
    - Disease risk is minimised by maintaining optimum fish health and ensuring a high-quality growing environment, with measures including precision feeding regimes, water quality monitoring, farm fallowing, cleaning and disinfection regimes, vaccination, health surveillance, net cleaning and bird exclusion netting.
    - The potential for natural pathogen spread to regional aquaculture sites is negated primarily by hydrodynamics and distance, with the main regional aquaculture hub in Big Glory Bay (Rakiura/Stewart Island) being approximately 24km from Hananui.

Summary of key marine biosecurity risks from the Hananui proposal, the mitigation required, and the assessed post-mitigation significance. Mitigation measures are outlined in a separate Biosecurity Management Plan. Incremental significance is assessed in the context of pre-existing risks, for which management is limited.

Key potential risk	Key potential effects	Key mitigation	Incremental significance post-mitigation
PATHWAYS			
Pathways from domestic source regions, especially vessels, introduce marine pests currently absent from region	New marine pest introduced to farm location that could subsequently spread	Management of external vessels and other external pathways, especially in relation to biofouling risk through adherence to strict 'clean hull' standards	**Negligible:** The 'clean hull' standard makes it highly unlikely that harmful species will be present on vessel entry to the region, and is supported by a regime of routine vessel inspection and hull maintenance, as well as other management measures. By comparison, there is limited management of other inter-regional pathways.
Pathways from domestic source regions, especially stock or equipment movements, introduce pathogens currently absent from region	New pathogen introduced into local waters, which could enter a naive wild finfish population	Movement of juvenile salmon from freshwater hatcheries, with biosecurity management and targeted health surveillance. Equipment cleaned and disinfected (or new) before entry.	**Negligible:** Sourcing juveniles from freshwater will eliminate risk of movement of seawater-specific pathogens. Use of hatcheries with biosecurity management plans and health surveillance systems (both targeted and non-targeted surveillance) will reduce the risk of pathogen entry via juvenile stock. Equipment can be thoroughly cleaned and disinfected to eliminate risk.
Regional pathways operating within project area carry established organisms	Incremental spread of organism already established in region	Effective management of regional pathways based on hull biofouling standards, cleaning and disinfection procedures, and other measures	**Negligible to minor:** Pathway management based on international biosecurity best practice will reduce regional risk to level considerably less than existing activities. Farm-related movements are locations already subject to considerable unmanaged pathway pressure.
FARM SCALE			
Reservoir of marine pests establishes on farm and facilitates subsequent spread	Local natural habitats and associated values (e.g. ecological values, fishery resources, natural character) adversely affected	Surveillance for organism, and maintenance of low biofouling levels on farm structures	**Minor:** Biofouling management will greatly reduce on-farm reservoir, but a residual risk remains to biogenic and coastal rocky reef. However, a more significant risk already exists due to regional vessel movements and natural dispersal from established organism populations.
Fouling organisms on farm infrastructure act as amplification reservoirs for mollusc pathogens	Increases infection pressure on the native flat oysters in the Foveaux Strait flat oyster fishery	Scheduled biofouling clearance timed to remove mussel and flat oyster settlement at periods when they are fragile and prior to peak infection intensity and shedding risk	**Extremely low:** By ensuring stock are managed in well-designed farm systems, given nutritious feed, handled carefully, and have an active health management system, stock on the farm are much less likely to become infected with endemic pathogens and express clinical disease, which is when maximal shedding occurs. Combined with a relatively low host density of wild fish outside the farm, the risk of amplification of pathogens in the farm to the point of an adverse effect on wild fish is minimised.
Stock held on the farms act as amplification sources for endemic finfish pathogens	Wild finfish passing or attracted to the farms are exposed to elevated levels of endemic pathogens	Best practice husbandry, management of on-farm stressors, high quality and nutritious feed, and an active animal health surveillance and response system, reduces the likelihood of farmed stock becoming infected at high levels with endemic pathogens and restricts their capacity to shed pathogens	**Extremely low:** By ensuring stock are managed in well-designed farm systems, given nutritious feed designed for the species and life stage, careful handling procedures and an active health management system, the stock on the farm are much less likely to become infected with endemic pathogens and express clinical disease, which is when maximal shedding occurs. When combined with a naturally relatively low host density of wild fish outside the farm, the risk of amplification of pathogens in the farm to the point of an adverse effect on wild fish is reduced to extremely low.

- The Expert Consenting Panel that evaluated the previous consent application under the COVID-19 Recovery (Fast-Track Consenting) Act was satisfied that "*with the imposition of conditions and implementation of a certified BMP, the biosecurity risk of the Proposal is likely to be minor…*". The single exception related to potential disease risk to the wild Bluff oyster fishery, with the specific issue of concern being risk due to the *Bonamia* spp. infection of oysters. Due to the proposed mitigation, as well as a change in the regional risk profile since the Panel's previous decision (primarily that non-native *Bonamia ostreae* is predicted to reach the oyster fishery within 7-14 years), an organism-specific risk assessment concluded that the incremental *Bonamia* spp. risk from Hananui to wild oyster populations was 'extremely low'.

Key conclusions from the Hananui biosecurity assessment in terms of the significance of development effects post-mitigation, as summarised in the Table on the previous page, are as follows:

- With effective management of risk pathways, especially from external domestic source regions, the risk of farm development and operations leading to the introduction and spread of harmful organisms in Southland will be no more than minor by comparison with most existing pathways for which management is limited.
- For harmful organisms already established in the Hananui operational region, the proposal may lead to local establishment in the farming area or wider environs, but the range of mitigation measures planned by NTS will greatly reduce risk.
- Despite mitigation through adoption of international best management, residual risks are inherent in all open water aquaculture operations, and cannot practically be eliminated. Nonetheless, with an effective BMP the overall incremental effect of the Hananui proposal is assessed as no more than minor.

As some of the mitigation detail cannot be finalised until operational activities are known, a recommended requirement is that the BMP is certified by Environment Southland, to provide assurance that it contains appropriate and effective measures that reflect best-practice biosecurity management.

1. INTRODUCTION

Ngāi Tahu Seafood (NTS) propose a salmon farming development, referred to as the Hananui Aquaculture Project (hereafter Hananui), in Foveaux Strait on the northern side of Rakiura/Stewart Island (Fig. 1). Among the ecological and broader environmental effects associated with such a development are potential marine biosecurity issues. Marine biosecurity in Aotearoa New Zealand refers to the management of risks posed by organisms that are potentially harmful to environmental, economic, social and cultural values (Hewitt et al. 2004). In the context of the Hananui proposal the two biosecurity aspects considered are:

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

Salt Ecology and Brightwater Partners were contracted by NTS to address both of these aspects, reflecting the complementary biosecurity expertise of the authors on marine pests and pathogens, respectively. This report:

- Provides contextual information on marine biosecurity in New Zealand, the regional profile of potentially harmful pests and pathogens, existing activities that contribute to biosecurity risk, and existing management measures.
- Describes proposal-specific activities and the incremental marine biosecurity risk they present, along with an outline of proposed mitigation measures. These measures are detailed in a separate standalone Biosecurity Management Plan (BMP) prepared by the report authors (NTS 2025).

The current report builds on and integrates the documents and information that formed part of a resource consent application considered by an Expert Consenting Panel under the COVID-19 Recovery (Fast-Track Consenting) Act in 2023. These documents were:

- A marine biosecurity assessment by Cawthron Institute (Morrisey 2019).
- A disease-specific risk assessment by DigsFish Services (Diggles 2019). This risk assessment was revisited from first principles to take new information into consideration, and is included as Appendix 1.
- A BMP by Salt Ecology and Brightwater Partners that addressed matters raised in reviews by Environment Southland and MPI biosecurity experts.

In the report we incorporate input from extensive consultation with stakeholders, including MPI and ES, and also respond to matters that were raised in the Expert Consenting Panel's decision to decline the original application.

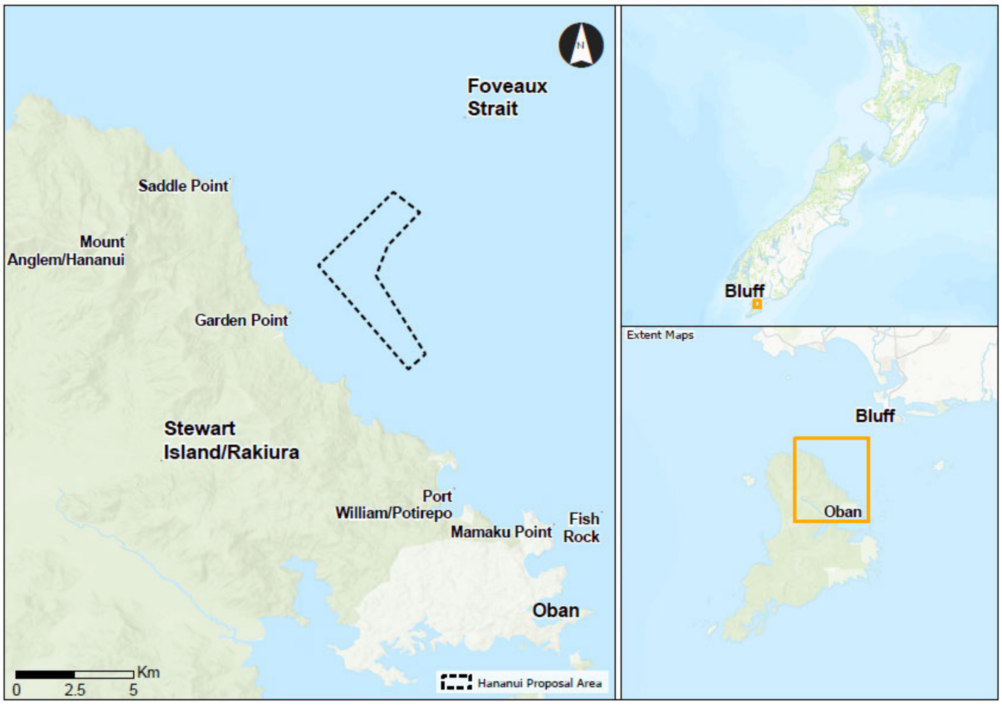


Fig. 1. Location of proposed Hananui Aquaculture Project salmon farming area.

2. OVERVIEW OF MARINE BIOSECURITY AND AQUACULTURE

Human activities in the marine environment can unintentionally spread marine organisms across barriers to their natural dispersal. Mechanisms include the discharge of ballast water carried by ships to aid stability, and organism transport as biofouling on submerged hull surfaces. In these ways, more than 200 non-native pests and pathogens have been accidentally introduced into New Zealand and subsequently become established (MFE 2019). The proliferation of some of these organisms in New Zealand coastal waters has caused significant adverse impacts on economic, ecological, cultural and social values.

To reduce biosecurity risks at the border, New Zealand has in place controls on international vessel biofouling (CRMS 2023), ballast water obligations under the International Convention for the Control and Management of Ships' Ballast Water and Sediments (IMO 2004), as well as standards for other pathways (e.g., maritime equipment). Despite these border controls, introduced species continue to arrive. Once established, most introduced species can seldom be eradicated, and there are few national-level controls on domestic activities, which commonly leads to their further spread around the country.

Hence, although initial incursions tend to be into ports and harbours, introduced species generally became geographically widespread due mainly to domestic commercial and recreational vessel movements and related mechanisms such as hull biofouling, domestic ballast water discharge, sediments (e.g., on anchors), entrainment in deck spaces (e.g. anchor lockers) and transport in retained water such as bilge water (Acosta & Forrest 2009; Sinner et al. 2009; Inglis et al. 2013; Fletcher et al. 2017). Movements of aquaculture vessels, equipment and stock have also been linked to the domestic spread of harmful organisms in New Zealand (Hunt et al. 2009; Castinel et al. 2015; Forrest & Fletcher 2015; Castinel et al. 2019). Following long distance human-mediated transport, the natural dispersal mechanisms of pests and pathogens (e.g., dispersal of microscopic planktonic life-stages in water currents) thereafter play an important role in facilitating spread and establishment at local and regional scales (Forrest et al. 2000; Fletcher et al. 2013).

As well as being an exacerbator of risk, aquaculture in New Zealand is vulnerable to pests and pathogens that are introduced from overseas and spread domestically. Furthermore, the farming environment can lead to the emergence of organisms (including endemic native species) that proliferate and become problematic to operations due to the unique conditions provided by aquaculture operations (see photos next page). As such, the industry has a strong incentive to manage risk.

Fig. 2 provides a high-level conceptual illustration of the role of aquaculture in marine biosecurity risk. The initial establishment of harmful organisms within farming areas can occur where risk organisms:

- Are already present in the local area, from where they may spread to the farm environment. For example, aquaculture structures provide a habitat for biofouling organisms that may themselves be problematic or may harbour pathogens.
- Are introduced by pathways from external sources. Movements of aquaculture vessels and equipment are generally the most significant pathways of relevance to both marine pests and pathogens, with additional considerations for disease transmission being movements of farming stock and people.

The development of significant reservoirs of harmful organisms in marine farm areas (e.g., proliferation of marine pests in biofouling, amplification of disease) can exacerbate their spread to the wider environment. The latter may be enabled by natural dispersal processes or through interactions between the farm reservoir and vessels or other transport pathways.

In the Hananui context, an important aspect of marine biosecurity illustrated in Fig. 2 is that marine pests and pathogens have the potential to establish and spread within regions due to factors and events unrelated to new aquaculture developments. As such, assessing the biosecurity significance of the Hananui proposal requires consideration of incremental risk in a regional context, and the extent to which risk mitigation is therefore necessary, justifiable, and worthwhile. The next section therefore considers the existing regional biosecurity context for the Hananui development.

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

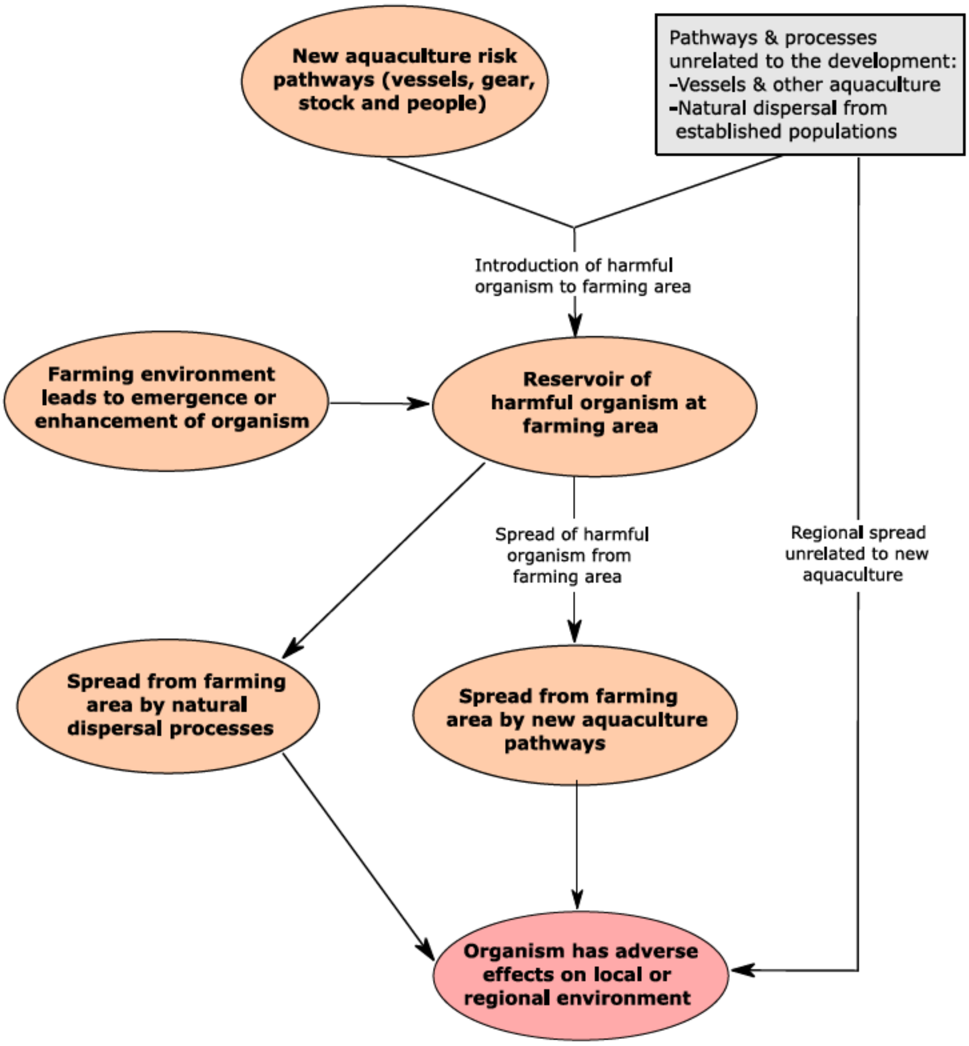


Fig. 2. Illustration of the generic processes potentially associated with the risk of introduction and spread of potentially harmful organisms due to aquaculture development. Orange ovals represent processes potentially arising from aquaculture operations. The grey rectangle represents risk to the farming area and wider region from anthropogenic and natural mechanisms of pest introduction and spread unrelated to aquaculture operations.

Aquaculture structures provide habitats on which potentially harmful organisms can become abundant if left unmanaged. Left: Carpet sea squirt *Didemnum vexillum* fouling salmon farm predator exclusion nets and blocking water flow (Bruce Lines, Diving Services New Zealand). Right: stinging sea anemones *Anthothoe albocincta* on salmon farm structures may contribute to skin lesions and secondary infections in cultured fish.

3. SOUTHLAND BIOSECURITY CONTEXT

3.1 RISK ORGANISMS AND IMPACTS

3.1.1 Marine pests

Despite the high number of introductions to New Zealand, only a few non-native species have been designated as marine pests, for example due to their actual or potential effects on areas of high ecological value or on economically important sectors such as aquaculture. A marine pest list developed by the Ministry for Primary Industries (MPI 2024) describes 15 species of concern, of which 10 have been recorded in New Zealand (Table 1). The Southland Regional Pest Management Plan (SRPMP 2019) lists seven marine pests as 'exclusion' or 'progressive containment' organisms. These are six of the species listed in Table 1 (marked with an asterisk), and the carpet sea squirt *Didemnum vexillum*.

In terms of the known distribution of these species in Southland, published records indicate the following:

- The Asian kelp *Undaria pinnatifida* is regionally widespread, being well-established in Bluff Harbour and Big Glory Bay (Hunt et al. 2009), some wave-exposed parts of the Southland coast (SRPMP 2019; Forrest & Stevens 2024), and parts of Fiordland (South et al. 2017; Gnanalingam & Hepburn 2019).
- *Didemnum vexillum* is established, but its distribution so far appears limited to Big Glory Bay.
- A single reproductively mature Mediterranean fanworm *Sabella spallanzanii* was found recently (July 2025) in Bluff and is the subject of ongoing surveillance to determine whether the species has established a viable population.

The above information may underestimate the true situation, as Environment Southland has only recently implemented a regional surveillance programme in some key areas (Rakiura, Fiordland, Riverton, Bluff and the Catlins).

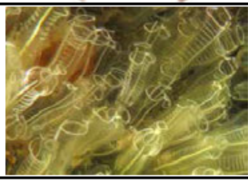
Of the other MPI pests in Table 1 that have not beeen recorded in Southland, most are assumed to have the ability to establish if transported into the region by anthropogenic pathways. The main exception is exotic *Caulerpa* (two species), which MPI have assessed as most likely being restricted to northeast New Zealand due to temperature limitations further south. It is also doubtful whether water temperatures in Southland are warm enough for the droplet tunicate *Eudistoma elongatum* (Page et al. 2011).

As well as the above designated pests, 38 additional marine non-native species have been recorded as established in Southland, of which 37 species have been recorded from Bluff Harbour where MPI-funded Marine High-Risk Site Surveillance is undertaken six-monthly (MBP 2025). There are also many additional species recorded in Bluff Harbour whose status as native vs non-native is unclear (e.g., Inglis et al. 2005). Five non-native species have been recorded from Rakiura and two from Fiordland. None of these additional non-native species have any formal designation as marine pests, but their regional presence in Southland is nonetheless significant given their potential to alter natural character and impact commercial and other values. For example, the vase tunicate *Ciona intestinalis* is present in Bluff Harbour and, while not a designated pest, has caused adverse effects on mussel aquaculture production in New Zealand and overseas (Forrest et al. 2014; Davidson et al. 2017).

Major challenges in predicting the potential impacts of marine pests arise from the lack of comprehensive studies for many species, and because invasiveness and impacts can change from place to place, and over time at a given location (Forrest & Taylor 2002; Fletcher et al. 2013; Atalah et al. 2019; Atalah et al. 2021). Predicting the consequences of marine pest spread into and within new regions therefore remains a significant challenge. The MPI (2024) marine pest guide describes a range of actual or potential effects from the pests already established in New Zealand, which include:

- Ecological effects due to changes to the structure or function of natural marine ecosystems.
- Economic effects on aquaculture and fisheries due to production loses, reduced marketability, disease emergence (next section), and costs of mitigation.
- A range of effects on marine infrastructure (e.g., due to biofouling weight, hydrodynamic drag).
- Effects on vessel operations (e.g., reduced fuel efficiency and increased greenhouse gas emissions).
- Adverse impacts on Māori cultural values and Treaty obligations.
- Reduced returns from tourism due to impacts on underpinning values.
- Risks to a range of other use values (e.g., recreational seafood gathering) and non-use values (e.g., natural character) associated with the marine environment.
- Human health effects.

Table 1. Marine pests listed by MPI (2024) that have established in New Zealand. Except for *Undaria*, none of these species have been recorded as established in Southland, although a recent find of Mediterranean fanworm in Bluff is currently under investigation. There are five additional marine pest species listed by MPI that have not been recorded in New Zealand.

Scientific name	Common name and/or group	Reported NZ distribution	Example
Caulerpa brachypus & C. parvifolia	Exotic Caulerpa (two species)	Multiple discrete locations in northeast New Zealand from Northland to Waikato	
*Charybdis japonica**	Asian paddle crab	Northland, Auckland and Waikato	
Clavelina lepadiformis & Clavelina oblonga	Light bulb ascidian & speckled ascidian	Ligh bulb (shown in photo): Whangarei, Auckland, Tauranga, Napier, Wellington, Picton, Nelson, Lyttelton, Otago Speckled: Aotea/Great Barrier Island	
*Eudistoma elongatum**	Australian droplet tunicate/ Colonial sea squirt	Multiple locations in northland and Auckland	
*Pyura doppelgangera**	Solitary sea squirt	Multiple locations in the north of Northland	
*Sabella spallanzanii**	Mediterranean fanworm / Tubeworm	Northland, Hauraki Gulf, Firth of Thames, Coromandel, Tauranga, Gisborne, Tasman, Nelson, Marlborough, Lyttelton, Timaru, Otago Harbour, Bluff (discovered July 2025, unclear whether a viable population has established)	
*Styela clava**	Clubbed tunicate / Solitary sea squirt	Northland, Kaipara, Hauraki Gulf, Firth of Thames, Coromandel, Tauranga, Wellington, Tasman, Nelson, Marlborough, Lyttelton, Otago Harbour	
*Undaria pinnatifida**	Japanese or Asian kelp / Large brown seaweed	Widespread nationally, including parts of Otago and Southland coastlines	

Notes:

MPI have assessed exotic *Caulerpa* spp. as most likely being restricted to northeast New Zealand due to temperature limitations further south. As such, *Caulerpa* is not considered to be of interest to the Hananui proposal.

Sabella spallanzanii is an 'unwanted' organism and also a notifiable organism under S45 of the Biosecurity Act. *Undaria pinnatifida* and *Styela clava* have both been declared as 'unwanted' organisms.

* Species maked with an asterisk, plus the carpet sea squirt *Didemnum vexillum*, are listed in the Southland Regional Pest Management Plan (SRPMP 2019) as 'exclusion' or 'progressive containment' pests.

Some of the most dramatic effects internationally have arisen through impacts on aquaculture, especially those caused by high abundances of biofouling organisms. Examples in finfish aquaculture are:

- Finfish stock losses, health declines, and product value downgrades from biofouling by anemones (see photo below Fig. 2) and/or hydroids, which are species that release stinging cells that appear to contribute to skin lesions and secondary infections in cultured fish (Atalah & Smith 2015).
- Biofouling that occludes pen nets and impedes water flow, such as historically described for *Didemnum vexillum* in Marlborough (see photo beneath Fig. 2). In such situations, dissolved oxygen can be depleted and flushing of finfish waste products reduced, leading to stress on fish stocks that may make them susceptible to pathogens.
- Impacts to infrastructure due to increased weight or drag, as described for *Undaria* in Marlborough, especially in locations with strong water currents (Sinner et al. 2000).

In addition, impacts on shellfish aquaculture in New Zealand illustrate the potential significance of biofouling for aquaculture generally. For example:

- The tunicate *Styela clava* had a devastating effect on mussel aquaculture in parts of eastern Canada (Ramsay et al. 2008), although effects of a comparable magnitude have not been observed in New Zealand to date.
- Effects on product harvesting and processing (e.g., physical interference) and/or loss of market value of product have been described for the Asian kelp *Undaria* (Sinner et al. 2000), the clubbed tunicate *Styela clava* (McFadden et al. 2007) and a range of other species (Heasman & de Zwart 2004; Jeffs & Stanley 2010).
- Direct losses of shellfish spat and crop have been attributed to biofouling overgrowth (Fletcher et al. 2013; Forrest & Atalah 2017).

Marine pests can also have a range of direct and indirect impacts on indigenous species and assemblages. Some examples among the designated pests are as follows:

- *Undaria* is considered to change the natural character of coastal habitats (Sinner et al. 2000). This type of effect is particularly noticeable where the kelp establishes in locations devoid of other canopy-forming brown algae (James 2016). A review for Australasia concluded that *Undaria* did not lead to significant ecological changes in most of the natural habitats of canopy-forming algae that it invaded, but effects were more evident in algal turf or barren habitats (South et al. 2017).
- One of the most dramatic examples of invasiveness in natural habitats is the establishment of *Didemnum vexillum* in deep-water (40-65m) natural pebble and cobble habitats more than 200km offshore from the coast of the northeast United States. In this location, *Didemnum* was recorded as covering a seabed area of 230km^2 (Valentine et al. 2007) and was reported to have a significant impact on the species composition of the benthic faunal assemblage (Lengyel et al. 2009).
- In New Zealand the Mediterranean fanworm (*Sabella spallanzanii*) is reported to have a range of structural and functional impacts in soft-sediment and hard substratum habitats (Fletcher 2014; Atalah et al. 2019; Tait et al. 2020).
- In the same way that *Undaria* alters natural character, the fanworm *Sabella*, as well as the sea squirts *Eudistoma elongatum* and *Pyura doppelgangera*, can also be conspicuous in natural ecosystems due to the high densities they achieve. Such effects are compounded for *Eudistoma* and *Pyura* due to their ability to establish intertidally.

Asian kelp *Undaria pinnatifida* on a mussel farm. This species is well established in Southland.

Mediterranean fanworm *Sabella spallanzanii* on mussel crop in the Hauraki Gulf (Kathy Walls, MPI). A single specimen of this species was recently found in Bluff, with follow-up surveys being undertaken to determine whether it has become established.

3.1.2 Pathogens

Unlike marine pests, no list of potentially harmful species have been formalised for pathogens. As such, Table 2 identifies potential organisms of interest that were subject to a systematic risk assessment process described in Appendix 1.

Part A of Table 2 lists potential risk organisms associated with salmonids, hence potentially salmon aquaculture. Part B lists those associated with ostreid (oyster) species. The latter is of special relevance to Hananui due to the recognised value of Foveaux Strait for the wild Bluff oyster fishery (*Ostrea chilensis*; aka flat or dredge oyster), and concerns identified in the previous Hananui consent application that farm development could exacerbate disease risk. Of particular concern to the oyster fishery is the parasite *Bonamia* spp. which includes the non-native *B. ostreae*.

By contrast with the marine pest list, which is based on a small subset of non-native species, the pathogen list comprises mainly species that are endemic to New Zealand. Table 2 nonetheless reveals four pathogen species or genera that have a legal designation as unwanted and/or notifiable.

Part A of Table 2 shows that there already exist a range of salmonid disease-agents in New Zealand. These represent either existing risks in the Hananui context or, where there is evidence of absence, make it appropriate that NTS implement mitigation measures to ensure that their activities do not lead to new introductions. The majority of ostreid risk organisms are likely to be present in Southland, so management is less about preventing entry, and more about limiting adverse amplification and release where the organism represents a true hazard. The risk assessment in Appendix 1 elucidates this situation, with the findings described as part of the assessment of effects (Section 4.6).

Table 2 shows that the listed salmonid and ostreid pathogens represent potential risks in the environment to wild fish, wild flat oysters and other bivalves, and aquaculture operations (including hatcheries). The incremental risk from the proposal with respect to these organisms must therefore be considered. Incremental risk does not mean the absolute occurrence or risk of a pathogen or its emergence, but how that occurrence may be influenced by the Hananui proposal.

Table 2. Pathogens that already exist in the waters of New Zealand and represent an existing risk of potential relevance to Hananui. A) Pathogens associated with salmonids, which are of direct relevance to salmon aquaculture; B) Pathogens associated with oyster species, which are of special relevance to Hananui due to the recognised value of Foveaux Strait for the Bluff oyster (*Ostrea chilensis*) fishery. These organisms have been subjected to the risk assessment described in Appendix 1. Grey shading represents species with a legal designation as unwanted and/or notifiable.

A. Existing salmonid risks

Pathogen	Legal status in NZ	NZ distribution	Impacts	Values at risk
Aquatic birnavirus	IPNV considered exotic, but aquatic birnavirus endemic.	Reported in Canterbury from salmonids and turbot in Wellington	Non-clinical in salmon, but associated with mortality in turbot in hatchery tanks	Potentially wild flatfish populations
Piscirickettsia spp. (incl. *P. salmonis* / NZ-RLO)	MPI notes NZ-RLO classified as P. salmonis; Classed as unwanted, but not notifiable	Issues in Marlborough Sounds; not currently detected further South than Akaroa Harbour	Summer mortality, systemic disease linked with high mortality	Marine salmon farms
Yersinia ruckeri O1b	Endemic; not notifiable or unwanted	Freshwater salmonid systems; NZ farmer priority pathogen	Septicaemia, mortality in trout/salmon	Hatcheries, freshwater grow-out
Tenacibaculum spp.	Endemic in seawater, not unwanted or notifiable	Established in NZ salmon farms; isolates published	Skin/gill lesions, high summer mortalities	Marine salmon farms; marine fish
Nocardia sp.	Endemic, not notifiable or unwanted	NZ wide distribution	Chronic granulomatous disease, persistent low-level losses	Salmon (tend to be species specific)
Vibrio spp.	Endemic, not notifiable or unwanted	Widespread in NZ marine waters	Ulcers, septicaemia; warm-period risk	Marine farms primarily
Paramoeba sp. & *Neoparamoeba perurans* (AGD)	Endemic, not notifiable or unwanted	Known from Marlborough and Big Glory Bay	Gill disease, growth suppression, mortality(very rare)	Marine pens

A. Existing salmonid risks (Table 2 continued)

Pathogen	Legal status in NZ	NZ distribution	Impacts	Values at risk
Hepatoxylon trichiuri	Endemic, not notifiable or unwanted	Marine parasite of wild fish	Cosmetic/processing issues	Wild fish
Derogenes varicus	Endemic, not notifiable or unwanted	Marine parasite; farm relevance low	Condition downgrade	Wild fish
Lecithocladium seriolellae	Endemic, not notifiable or unwanted	Recorded in NZ marine fish	Minor impact	Wild fish
Parahemiurus sp.	Endemic, not notifiable or unwanted	Marine parasite; low farm impact	Minor	Wild fish
Tubulovesicula angusticauda	Endemic, not notifiable or unwanted	Marine parasite; low farm impact	Minor	Wild fish
Phyllobothrium sp.	Endemic, not notifiable or unwanted	Marine elasmobranch cestodes	Cosmetic/processing issues	Wild fish
Heduris spinigera	Endemic, not notifiable or unwanted	NZ marine fish parasite	Cosmetic/condemnation risk	Wild fish
Hysterothylacium sp.	Endemic, not notifiable or unwanted	Common in NZ wild marine fish	Fillet defects, consumer complaints	Wild fish
Eustrongylides sp.	Endemic, not notifiable or unwanted	Sporadic in wild fish	Fillet defects	Wild fish
Paenodes nemaformis	Endemic, not notifiable or unwanted	Sparse data; negligible farm relevance. Reported once from freshwater in 1962.	Minimal	Freshwater salmonids
Caligus longicaudatus	Endemic, not notifiable or unwanted	Sea lice rarely present in NZ salmon farms	Irritation, secondary infections	Marine pens
Cirolana sp. & *Nerocila orbignyi*	Endemic, not notifiable or unwanted	Marine ectoparasites present in NZ	Stress, lesions on affected fish	Marine pens (warm months)
Flavobacterium sp. (freshwater)	Endemic, not notifiable or unwanted	Common in freshwater hatcheries	BCWD/RTFS; egg/ovarian-fluid association so can have vertical transmission	Freshwater hatcheries
Flavobacterium psychrophilum	Endemic, not notifiable or unwanted	Likely present in NZ hatchery environments	Bacterial cold-water disease; fry losses	Freshwater hatcheries
Bacterial gill disease (*F. branchiophilum*)	Endemic, not notifiable or unwanted	Expected in intensive freshwater salmonid culture in NZ	Gill pathology, respiratory compromise	Freshwater hatcheries
Pasteurella sp.	Endemic, not notifiable or unwanted	NZ distribution unclear	Septicaemia events under stress/temperature spikes	Hatcheries, marine pens
Streptococcus sp.	Not notifiable or unwanted	No clear geographic presence documented	Acute septicaemia, high mortalities in warm water	Warm-water aquaculture, RAS
Myxobolus cerebralis	Historical NZ detection (1993 survey); Unwanted organism	Detected in hatchery context	Skeletal deformities, survivorship reduction	Trout hatcheries, wild trout fisheries
Cochliopodia sp.	Endemic, not notifiable or unwanted	Likely present at low levels in freshwater biofilms	Gill/skin irritation under poor water quality	Freshwater hatcheries
Chilodonella sp.	Endemic, not notifiable or unwanted	Common protozoan parasite globally; expected across all NZ	Skin/gill parasitosis; acute hatchery losses	Freshwater hatcheries
Ichthyophthirius multifiliis	Endemic, not notifiable or unwanted	Well known in NZ aquaria/freshwater	Rapid outbreaks; high juvenile mortality	Freshwater hatcheries, ornamental supply chains

B. Existing ostreid (oyster) risks (Table 2 continued)

Pathogen	Legal status in NZ	NZ distribution	Impacts	Assets at risk
Herpes-like virus (OsHV-1 and related)	OsHV-1 µVar notifiable, unwanted organism	Detected in Pacific oysters (*Crassostrea gigas*) in NZ	Mass mortalities in juvenile oysters; major aquaculture losses	Oyster aquaculture (Pacific oysters, spat supply)
Intracellular bacteria	Endemic, not notifiable or unwanted	Reported in NZ shellfish (clams, oysters)	Reduced growth, mortality, condition loss	Bivalve aquaculture, wild shellfish beds
Vibrio spp.	Endemic, not notifiable or unwanted	Marine environment in NZ; documented in oysters and finfish	Summer mortalities in shellfish, ulcers/ septicaemia in fish	Shellfish farms, salmon farms, hatcheries
Bonamia ostreae	Listed unwanted organism in NZ	Detected in flat oysters (*Ostrea chilensis*) in Marlborough & Stewart Island since 2015	High mortalities in flat oyster beds; movement restrictions	Bluff oyster fishery, restoration beds
Bonamia exitiosa	Endemic in NZ; confirmed since 1980s	Widespread in *Ostrea chilensis* populations (Foveaux Strait, Marlborough)	Historic collapse of Bluff oyster fishery	Wild oyster beds, oyster aquaculture
Apicomplexan X	Endemic, not notifiable or unwanted	Detected in NZ shellfish histology surveys (clams, oysters)	Unclear impact; potential pathology under heavy infection	Shellfish beds
Klossia-like coccidian	Endemic, not notifiable or unwanted	Recorded in NZ bivalves (histological studies)	Coccidian stages in digestive gland; unclear impact	Bivalve aquaculture
Bucephalus longicornutus	Endemic, not notifiable or unwanted	Known from NZ cockles and other bivalves, e.g., *Ostrea chilensis*	Castration and reduced reproductive output in hosts	Wild cockle beds, small-scale fisheries
Microsporidium rapuae	Endemic, not notifiable or unwanted	Described from NZ pāua (*Haliotis iris*) and oysters; endemic	Muscle lesions, potential growth impacts	Pāua fishery and aquaculture
Pseudomyicola-like copepods	Endemic, not notifiable or unwanted	Observed in NZ shellfish (mussels, oysters)	Gill/respiratory irritation; reduced condition	Mussel/oyster farms
Polydora sp. and *Boccardia* sp.	Endemic, not notifiable or unwanted	Widespread in NZ oyster and mussel farms	Shell boring, mud blisters; product downgrade	Mussel and oyster aquaculture, wild shellfish beds

3.2 PROFILE OF EXISTING RISK ACTIVITIES

The Southland region is subject to a significant pre-existing marine biosecurity risk due primarily to international and domestic vessel traffic, and commercial activities that include significant aquaculture operations in Big Glory Bay.

Vessel pathways

Bluff is the main regional hub of domestic and international vessel activity. This includes movements of vessels of all sizes and types, such as bulk carriers, container ships, tugs, fishing vessels, dredges, cruise vessels and recreational boats (Dodgshun et al. 2007; Hayden et al. 2009a).

Data from 2000-2005 reported by Hayden et al. (2009a) indicated 1,117 arrivals of merchant vessels >99 tonnes to South Port, of which a high proportion (42%) were bulk carriers. More recent data from South Port (https://southport.co.nz/) indicates 305-349 cargo ship visits to the port annually over the last five years. Fig. 3 provides a density map of vessel traffic to illustrate the international (Fig. 3a) and inter-regional (Fig. 3b) connectedness of the Foveaux Strait area by vessel movements. Vessels arrive at Bluff from outside the region for offloading alumina, petroleum products, fertiliser, acid, stock food and cement; and export of aluminium, timber, logs, dairy, meat by-products, fish and woodchips. Vessels arrive directly or indirectly from most ports in New Zealand, and international vessels originate from ports mainly in Australia, but also Europe, Asia and the United States. Vessel pathways include connections with source ports in New Zealand and overseas that have established populations of many of the pests and pathogens described in Section 3.1. For example, Fig. 3 illustrates the region is connected to ports in:

- Otago Harbour, Lyttelton Harbour and harbour environments further north in New Zealand, which have several high-risk species that have not been recorded in Southland (Table 1).
- Tasmania and Melbourne (Port Philip Bay), which have populations of the Northern Pacific seastar *Asterias amurensis*, which is a high-risk species not yet recorded in New Zealand.

Near the proposed Hananui farming area there are two designated anchorages for ships delayed by weather or waiting to berth in South Port - one directly inshore of the proposed farms and one ~6km to the north. Over 2017-2019, a total of 90 vessels (e.g., cargo ships, tankers) are reported to have used these anchorages.

In addition to inter-regional and international pathways, there are numerous within-region movements of vessels, such as those associated with fishing (e.g., oyster dredging, finfishing, trawling) and aquaculture, at least two commercial charter operators, the Foveaux Freighter, and a ferry that operates between Bluff and Stewart Island. Outside Bluff, there is considerable commercial vessel activity in Paterson Inlet, much relating to mussel and salmon aquaculture in Big Glory

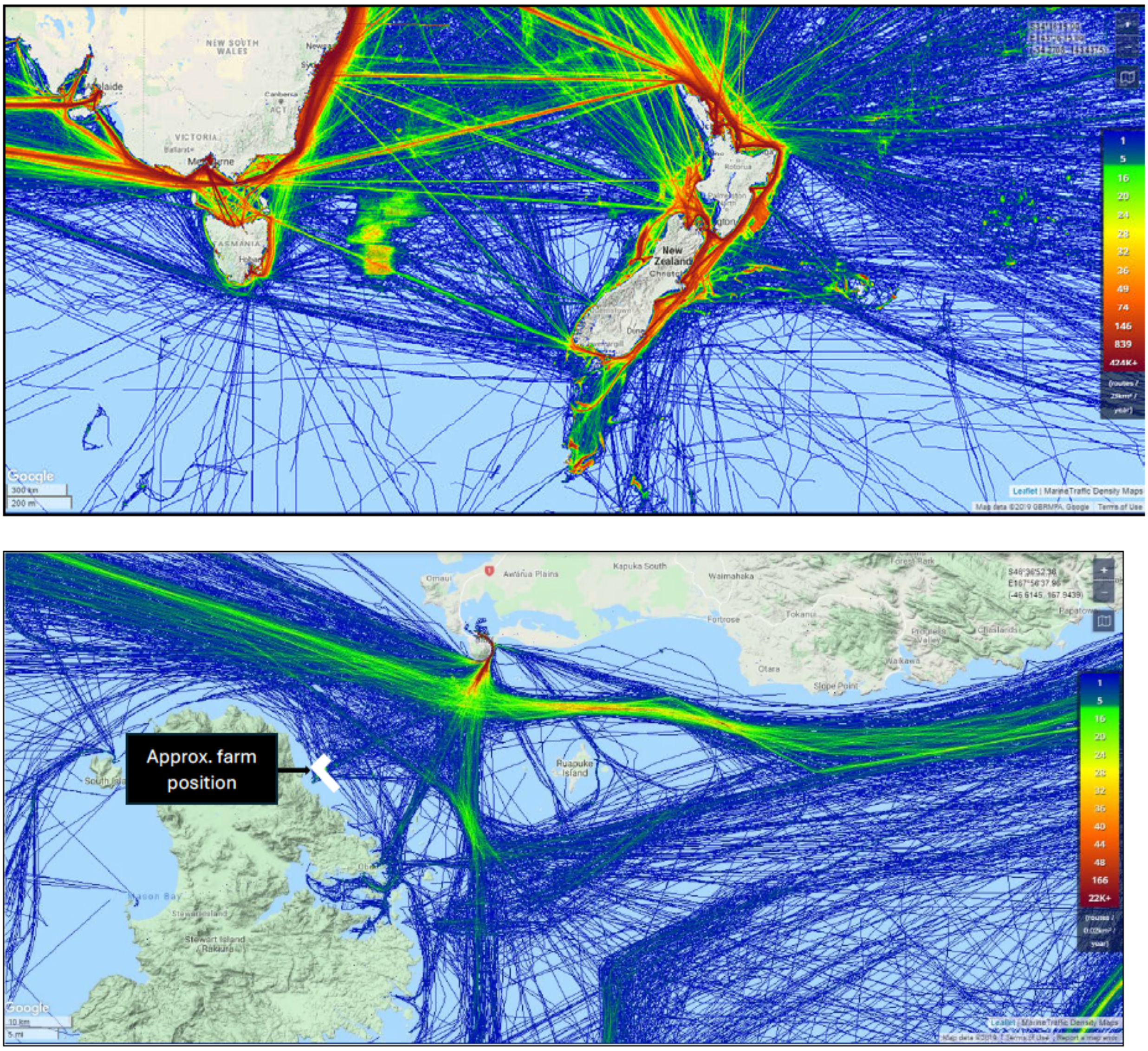


Fig. 3. Vessel pathway density with international (routes/23km^2/yr; top) and regional (routes/0.02km^2/yr; bottom) pathways illustrating the high connectedness of the application area by vessels (not including vessels without tracking systems, i.e., excluding most recreational vessels). The approximate Hananui farming area is shown by the white "L" shape on bottom image. Source: www.marinetraffic.com.

Bay (see below), but additional vessel activity arises from movements of tourist charters, cruise ships, research vessels, and water taxis.

Compared with many other locations in New Zealand, recreational vessel numbers appear to be quite low across the Southland region as a whole (Dodgshun et al. 2007), but private vessels may visit from outside the region. Even low numbers of in-water recreational boats (i.e., those moored/berthed in-water, rather than trailer boats) may 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 accumulate biofouling during idle periods, slow voyage speeds that enable many biofouling organisms to survive, voyage patterns that can involve visits to relatively remote and pristine coastal areas, and direct interactions with aquaculture (e.g., recreational boats may fish around marine farms).

Aquaculture

There are 46 consented marine farms in the Southland region, cultivating salmon, mussels and oysters. The majority (36) are in Big Glory Bay (Stewart Island), with 7 farms in Bluff Harbour and 3 in Horseshoe Bay (Stewart Island). Marine farms occupy a total of ~290ha of consented area. Following an outbreak of *Bonamia ostreae* in early 2017, several thousand tonnes of oysters were removed from Big Glory Bay and the future of oyster farming in Southland remains unclear.

These existing activities present several potential sources of biosecurity risk. Compounding the risk from general vessel movements are the associated movements of aquaculture stock and equipment (e.g., rope, floats, harvest equipment). Shellfish aquaculture stock and equipment transfers have historically exacerbated the domestic spread of at least four of the marine pests described above - *Undaria*, *Didemnum*, clubbed tunicate (*Styela clava*) and Mediterranean fanworm (e.g., Forrest & Hopkins 2013). Additionally, shellfish aquaculture has been linked to pathogen spread in New Zealand (Castinel et al. 2015; Castinel et al. 2019). With the relatively recent implementation of pathway control and other aquaculture biosecurity measures (see Section 3.3), the role of aquaculture as an exacerbator of risk to Southland is likely to be diminished compared to the historic situation.

Risk mechanisms

The actual risk mechanisms for pest and pathogen transport into and within Southland will depend on the particular pathway, but key examples are as follows:

- Biofouling is expected to be a risk mechanism on all vessel types (Inglis et al. 2010; Forrest 2018; Davidson et al. 2021; Fuhrmann et al. 2021; Georgiades et al. 2021; Hopkins et al. 2021) and can be important for aquaculture equipment and shellfish stock as noted above. The data of Stuart (2002) indicate that regional vessels in southern New Zealand may carry an extensive suite of fouling organisms, including groups that contain recognised marine pests (e.g., sea squirts). The spread of pests by biofouling is especially important for vessels that travel at speeds slow enough (<10 knots) that enable the survival of associated species (Coutts et al. 2010a; Coutts et al. 2010b; Hopkins & Forrest 2010). Biofouling in turn may be a vector for the spread of pathogens (Costello et al. 2021; Fuhrmann et al. 2021; Georgiades et al. 2021).
- Ballast water risk will likely be most important for ships that discharge ballast to maintain stability and draft when loading cargo, and is a potentially important mechanism for water-borne pathogens (Ruiz et al. 2000; Dobbs et al. 2013; Ng et al. 2015), or the planktonic life-stages or viable fragments of pests (Drake et al. 2007; Hewitt et al. 2009). For example, studies have shown the presence of pandemic serotypes of *Vibrio cholerae* and other harmful organisms in ballast water and harbour waters, highlighting the risks associated with maritime operations.
- Pipework and hull recesses on large vessels known as 'sea chests' can also be important, as they can contain considerable biofouling. Sea chests can harbour adult life-stages of mobile organisms such as crabs, fish and sea stars (Coutts & Dodgshun 2007; Frey et al. 2014).
- Sediments are recognised as a potentially important mechanism for the transport of harmful organisms or resting stages such as cysts, and may be associated with ballast water, anchors and ground tackle (chains, ropes, etc.), aquaculture gear, and shellfish stock (Drake et al. 2007; Hewitt et al. 2009; Padilla et al. 2011)
- Other vessel-related mechanisms also potentially exist and are potentially relevant in a Southland context. These include:
    - Debris/fragments on deck areas. For example, seaweed spore or viable fragments can occur in gear and deck spaces (e.g., rope, nets, anchor lockers) and potentially survive long distance transport (Sant et al. 1996; Schaffelke & Deane 2005; Forrest & Blakemore 2006). The exotic

Caulerpa species that have become established in northern New Zealand are likely spread by such mechanisms.

    - Retained water such as bilge water (Acosta & Forrest 2009; Darbyson et al. 2009; Sinner et al. 2009; Fletcher et al. 2017). For example, a survey of 30 small vessels operating within the Top of the South region identified (using molecular methods) 118 taxa within bilge water (Fletcher et al. 2017).

- For aquatic pathogen transfer, the movement of people is recognised as a potential significant mechanism, as human activities can play a significant role in spread. Although not specific to marine aquaculture, some general examples include:
    - Recreational angling: The release of live baitfish by anglers, as well as poor hygiene practices such as failing to disinfect or dry equipment between water bodies, have been linked to increased risk of introducing fish pathogens to new environments (McEachran et al. 2023; Mahon et al. 2018; Anderson et al. 2014). Studies have found that bait shop water contains a variety of fish and human pathogens, suggesting that disposal of bait water can also act as a contamination route. Outbreaks of white spot syndrome virus (WSSV) in Australia have been linked to use of imported raw, frozen prawns as bait by recreational fishers.
    - Additionally, contaminated equipment has been implicated in the spread of crayfish plague, with spores of *Aphanomyces astaci* transferred between catchments on wet gear (Brady et al. 2024).

  These findings underscore the importance of human-mediated activities in shaping the dynamics of aquatic pathogen movement and highlight the need for stringent biosecurity measures across sectors.

3.3 EXISTING BIOSECURITY RISK MANAGEMENT

International pathways

As noted in Section 2, vessels arriving from international source regions are subject to border standards for biofouling, ballast water and sediment. Further detail on the main management measures for international pathways is as follows:

- A Craft Risk Management Standard (CRMS) for biofouling (CRMS 2023) requires that vessels arrive in New Zealand with a 'clean hull'. In effect, the CRMS allows a small amount of hull biofouling on 'short stay' vessels, which are those in New Zealand for no more than 28 days. For vessels staying longer, biofouling is restricted to no visible macrofouling other than gooseneck barnacles.
- Ships must have a ballast water management plan to guide the crew in the management of ballast water and sediments. As of late 2024, international ballast water must be treated to a specified standard before discharge, to kill or reduce the number and size of viable organisms or concentrations of pathogens (MNZ 2023). Ballast water regulations enable exemptions in some circumstances. The majority of vessels discharging ballast water in New Zealand appear to be meeting treatment requirements. Data provided by MPI show that during the period from 1 August 2024 to 31 July 2025, Biosecurity New Zealand recorded 1,010 arriving vessels that intended to discharge ballast water. Of those, 916 treated their water using approved treatment systems before discharging, 45 conducted mid-ocean ballast water exchange, and 49 used a combination of approved treatment systems and mid-ocean exchange.

Inter-regional and regional pathways

There are no controls on ballast water discharge from ships travelling between New Zealand ports, meaning that this mechanism remains a risk on domestic pathways. Management of other mechanisms on domestic pathways in New Zealand is limited, differs among regions and sectors, and lacks national consistency. For example:

- Environment Southland has in place a Fiordland Marine Regional Pathway Management Plan (SRC 2017), which involves a Clean Vessel Pass system whereby vessels going to Fiordland are required to meet strict standards for hull biofouling (equivalent to the CRMS short stay vessel standard noted above), topside gear, and residual seawater (i.e., seawater held on board such as in seafood tanks and non-oily bilge water).
- There are existing or proposed controls on vessel biofouling and/or equipment transfers in some other regions (Top of the North, Top of the South, Subantarctic Islands). However, the management requirements differ greatly among locations, and there are no national-level restrictions on domestic vessel biofouling or equipment transfers.

Aquaculture

At the sector level, aquaculture management measures are relatively well developed across a range of risk mechanisms. Of relevance to Southland are the following:

- Controlled Area Notice (CAN) provisions have been implemented by MPI since 2017 to minimise the risk of spreading the non-native parasite *Bonamia ostreae* in southern New Zealand (MPI 2023). The Hananui farming area falls within a 'Lower South Protected Zone' (LSPZ; Fig. 4), for which management measures include a requirement that "*Gear must not be moved into the zone unless it is visibly free of fouling*".
- The CAN contains additional requirements (e.g., for vessels) for movements into or out of a 'Big Glory Bay contained zone'. The Hananui operation would not impinge on the contained zone, and would operate wholly within the LSPZ. The extent of compliance with the various CAN requirements in the different zones is unclear.
- Aquaculture New Zealand (AQNZ) has produced biosecurity standards for salmon, mussel and oyster aquaculture (AQNZ 2023, 2024b, a). AQNZ defines a number of Operational Zones in New Zealand, with the 'Lower South' zone encompassing Otago and Southland. There are specific biosecurity requirements for movements between Industry Operational Zones, which for salmon farming address stock, equipment, vessels, feed, water and people. The existing programme for the salmon industry does not prohibit movement of equipment or salmonids including broodstock, juveniles and gametes between operational areas of New Zealand, but does require disinfection standards and some degree of health surveillance.
- Salmon farms in Big Glory Bay are operated by Sanford Ltd under their own biosecurity management plan and, as part of the consenting process for new marine farms (or consent renewals), Environment Southland may impose coastal permit conditions relating to marine biosecurity. An example from a recent (February 2025) coastal permit for a shellfish farm in Big Glory Bay includes requirements that:
    - Shellfish spat be locally sourced or, in the case of green-lipped mussel spat, sourced from Ninety Mile Beach (aka 'Kaitaia' spat). This requirement reduces risk associated with transfers from high risk spat/seed sources such as the top of the South Island.
    - Used equipment or materials from other geographic coastal marine areas must be thoroughly cleaned and sterilised before transport to the marine farm site.
    - Marine farming structures are to be maintained free of unwanted organisms and pests as identified by MPI or SRPMP (2019).
    - Any removed unwanted organism or pest must be disposed of at an authorised land disposal site.
    - A Biosecurity Management Plan (BMP) must be developed for certification by Environment Southland to "*…address measures to avoid the introduction, exacerbation and spread of any marine unwanted organisms…and minimise any impacts through propagation on the marine farm if any such species are introduced*". Box 1 describes the key matters the BMP needs to consider, as prescribed in the coastal permit.

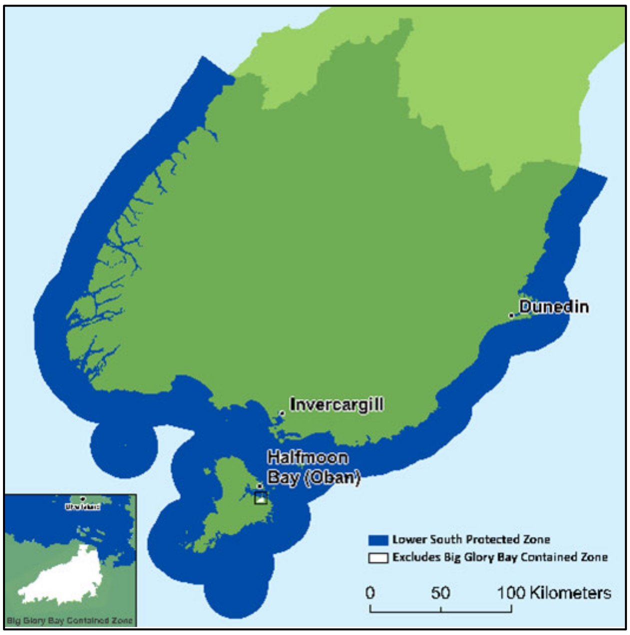


Fig. 4. Lower South Protected Zone (blue shade) for which there are rules relating to equipment movements to minimise the risk of spreading the flat oyster parasite *Bonamia ostreae*, to protect the Bluff oyster fishery.

Other controls

- The Asian kelp *Undaria* has been the subject of eradication efforts in Breaksea Sound (Fiordland), but these have been ineffective at containing its spread (Gnanalingam & Hepburn 2019). However, control efforts have been successful in some other locations. *Undaria* is listed as a 'progressive containment' species in the SRPMP (2019), with an objective (and associated rules) that aim to progressively contain and reduce its geographic distribution and prevent further infestations.
- Outside Fiordland, the proposed Hananui farming location is within a Southern *Undaria* Exemption Area (Fig. 5), for which vessels operating exclusively within this area are exempt from SRPMP (2019) Rule 13 that requires they be free of *Undaria*. The rationale is that *Undaria* is well established in suitable habitats across this area, such that its management would have no significant benefit.

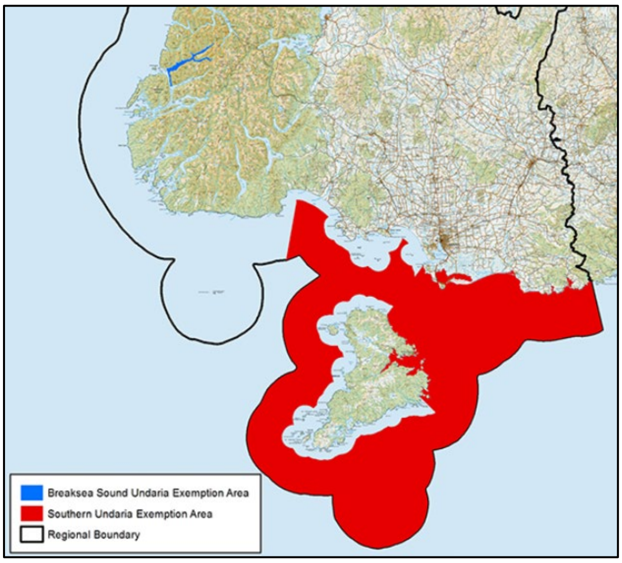


Fig. 5. Southern *Undaria* Exemption Area (red shade) where vessels do not need to meet SRPMP (2019) requirements to be free of Asian kelp.

Box 1. Example from a recent shellfish farm consent in Big Glory Bay, showing matters specified by Environment Southland that are required to be addressed in a Biosecurity Management Plan

a) Details of the marine pests, unwanted and notifiable organisms and marine fouling organisms, identified by the Ministry for Primary Industries, Council and the marine farming industry, as requiring identification and recording;

b) Processes to be applied by staff operating the marine farm and vessels servicing the marine farm to inspect, identify, record and report to the Council on species identified in (a), as well as any marine pest species new to the area;

c) Timing of reporting to the Council under (b);

d) Measures that will be undertaken to avoid the introduction, exacerbation and spread of species identified in (a);

e) Actions that will be undertaken if any new organisms are observed;

f) Measures to be taken to educate and train farm staff operating the marine farm on biosecurity requirements and responsibilities; and

g) Processes and timing for reviewing and updating the Biosecurity Management Plan.

An annual review of the BMP by the consent holder is required. The consent holder is required to ensure that all farm staff are trained in accordance with the requirements of the BMP to be aware of the presence of any strange or unfamiliar marine and terrestrial species on farm related vessels, vehicles, structures, machinery and equipment.

Before any vessel or equipment used in construction and/or maintenance is brought to the marine farm from outside the Southland Region, Council biosecurity staff shall be notified of the planned activities, and may require an inspection for unwanted or risk species by a suitably qualified and experienced person.

In the event that a bay wide review of biosecurity measures is undertaken, the consent holder is required to reconsider the Biosecurity Management Plan and propose amendments to ensure consistency with the outcomes of the bay wide review.

4. ASSESSMENT OF EFFECTS OF HANANUI DEVELOPMENT

4.1 HANANUI AQUACULTURE PROJECT OVERVIEW

Hananui is a two-stage salmon farming development located 2-6km off the northern coast of Rakiura/ Stewart Island, and proposed to occupy ~1,285ha of the Coastal Marine Area. Water depths in the farming area range from approximately 20 to 40m. Within this area four marine farms are proposed (Fig. 6). The development stages are as follows:

- Stage 1 involves the establishment of a block of 10 sea pens (arranged in a 5x2 configuration) at each of the four marine farm sites, and a feed discharge of 15,000 tonnes per annum.
- Stage 2 of the project would see the overall feed discharge rise to 25,000 tonnes per annum with the introduction of a second block of 10 sea pens at each of the four marine farm sites.

Moving to Stage 2 would be subject to environmental monitoring over two production cycles at the Stage 1 feed input.

The farm locations have been selected based on multiple drivers – including separation distances between marine farms for biosecurity purposes (see Section 4.3 below), distance to Rakiura, distance to high-value biogenic habitat (Fig. 6), and landscape values.

Key features of the marine farms and pens are as follows:

- The two blocks within each farm will be separated by approximately 300m.
- There will be one feed barge associated with each marine farm.
- Net pens will be 168m circumference polar circle type.

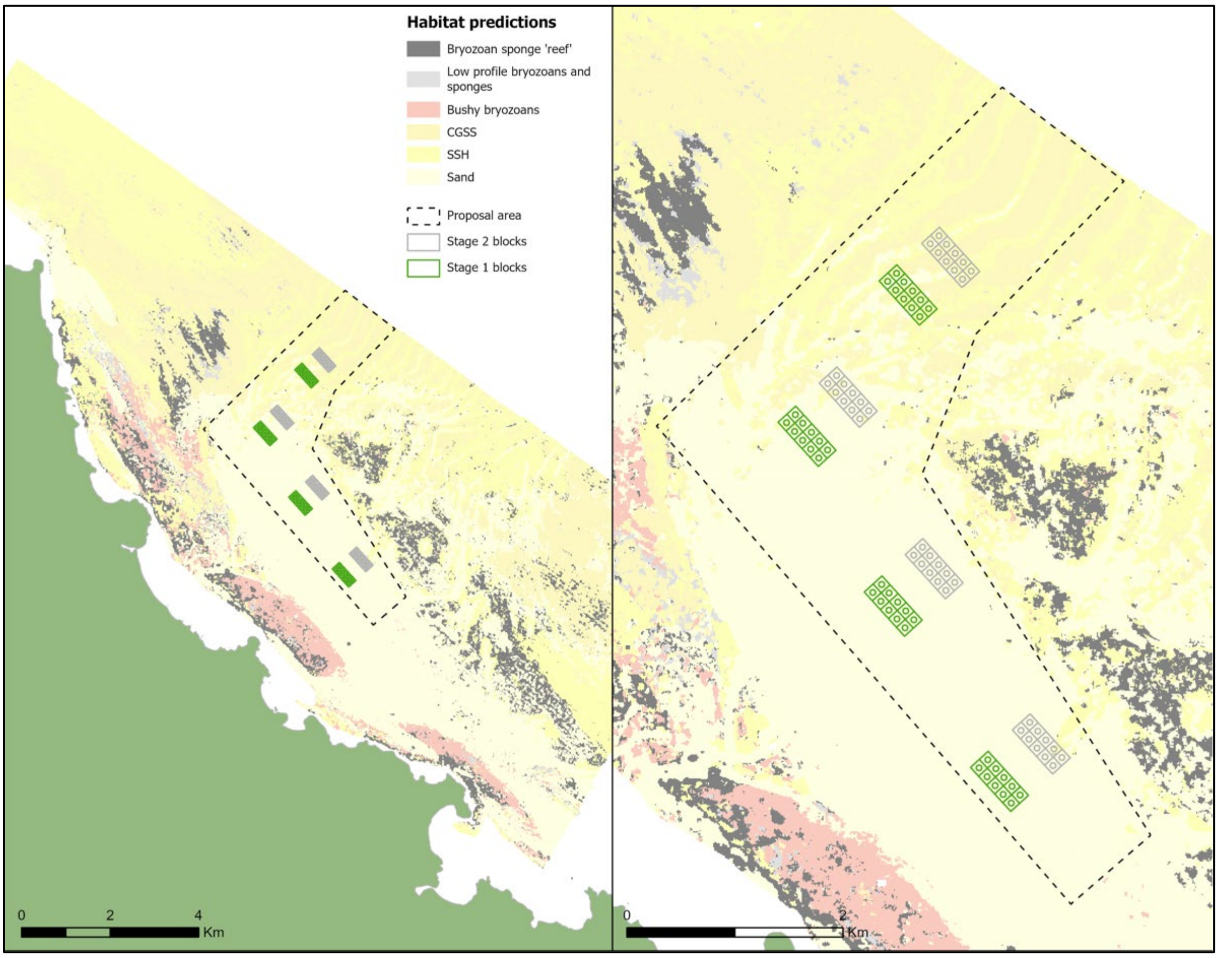


Fig. 6. Hananui Aquaculture Project proposed farming area and layout relative to biogenic habitats. The farming area has 4 marine farms, which at full development will each consist of two blocks of 10 pens.

- A single net will be used for each pen.
- The maximum net depth will be 22m. However, a minimum 5m clearance will be kept between the bottom of the pen and the seabed. This means that in some instances the net depth will be less than 22m. A net schematic is shown in Fig. 7. Pens will be fixed to the seafloor with a series of anchors, with rope and chain warps.

NTS is proposing single year class farming at each marine farm. The four proposed farms will be sequentially stocked so that at any given point in time one has just had smolt introduced, one is mid-production cycle, one is approaching harvest, and one is in a fallow period.

A full rotational cycle will be of approximately 25-27 months duration, consisting of 16-18 months production, 6 months harvesting and 3 months of fallowing. This approach contrasts with some of the current New Zealand finfish aquaculture industry where, in order to maintain harvest supply throughout the year, new generations of fish may be introduced to a site containing older fish (resulting in multiple year classes on any one site).

4.2 GENERAL APPROACH TO THE MARINE BIOSECURITY ASSESSMENT

The approach to the assessment for pest and pathogen risk is as follows:

- Marine pests: MPI and Environment Southland have already designated a small subset of non-native species as pests, as described in Section 3.1.1 (see Table 1). As such, potential risks are discussed qualitatively in preference to undertaking a systematic risk assessment. The focus is understanding the generic potential for adverse effects, and ensuring that effective mitigation is in place to minimise risk to an acceptable level, irrespective of the known or perceived magnitude.
- Pathogens: Although some organisms have a designated biosecurity status (e.g., 'notifiable', see Table 2), disease issues in some cases are poorly understood, and harmful organisms can include ubiquitous endemic environmental pathogens with the potential to thrive in an aquaculture setting. As such, to deal with uncertainty, and identify the organisms for which specific steps to mitigate risk are deemed necessary (i.e., to separate potentially harmful species from those of no concern), the systematic risk assessment described in Appendix 1 was undertaken.

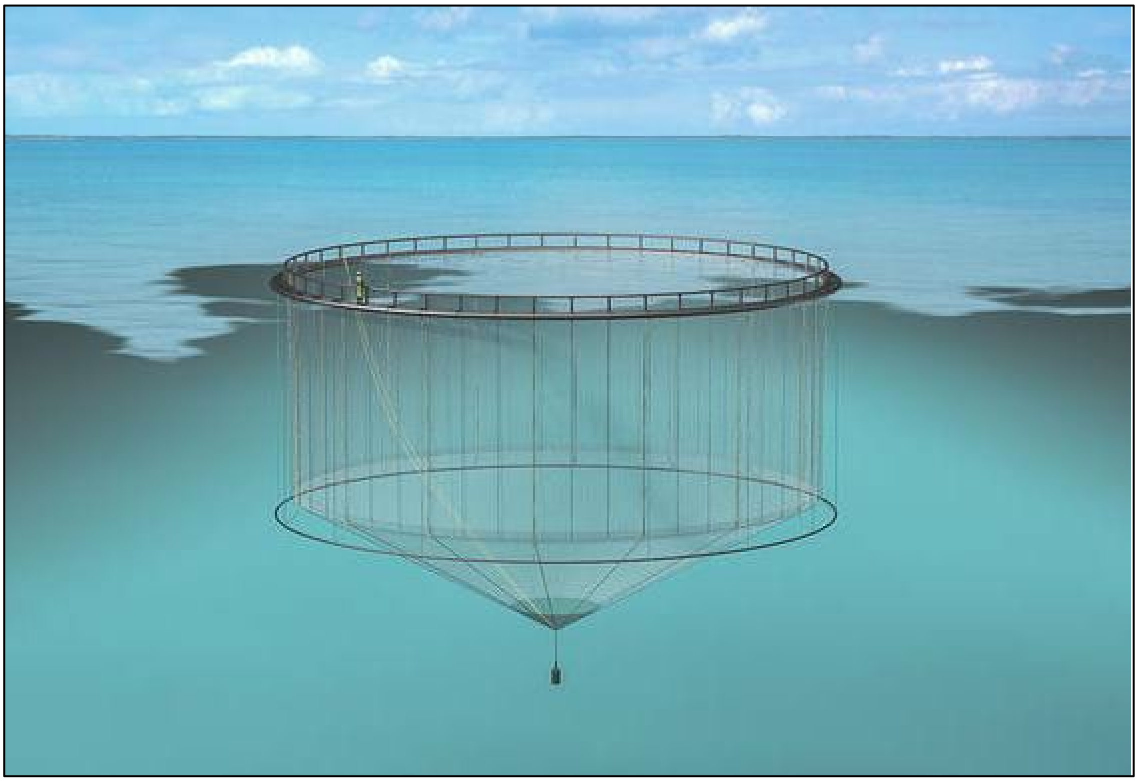


Fig. 7. Hananui Aquaculture Project schematic of net pen general configuration. (source: DSA Ocean Hananui Aquaculture Site – Front-End Engineering Design Report)

4.3 BIOSECURITY LIMITATIONS OF THE FARMING AREA

An issue identified by MPI in the previous application, and evident from Fig. 6, is that the Hananui farms are close to each other, and therefore lie within the same epidemiological area for inter-farm pathogen transmission, i.e., meaning that disease on one farm block may spread within the farming area. Below we therefore consider the risk of pathogen spread from a primary farm site of emergence to a secondary site.

The probability of a pathogen establishing on a secondary site is related to the amount of pathogen being shed at the primary site (dependent on the rate of shedding and the number of infected animals), the water current speed (and direction), the distance to the secondary site, the rate of decay of the pathogen in the environment, the transmissibility of the pathogen, and the size of the infectious dose required. Because of the range of variables, and the range of values for these variables for different pathogens, a wide range of separation distances have been elucidated dependent on the pathogen involved. Based on international literature:

- Green (2010) indicated that distances of 8-20km were needed for infectious salmon anaemia virus (ISAV).
- Chambers and Ernst (2005) showed that a distance of at least 8km was required for management of a specific monogenean parasite in finfish farms.
- Mardones et al. (2011) reported that for ISAV, control zones of 10-15km were most appropriate. Farm-level linkage of HSMI infection (Heart and Skeletal Muscle Inflammation) has been proposed at 15km distances.
- Murray (2006) reported on ISAV control zones that varied from 3.6 km to 7.2km. In addition, Salama and Murray (2011) demonstrated for ISAV that farms separated by 5km could be expected to become completely infected, with farms 10km apart resulting in 88% infection of the population.
- Aldrin et al. (2010) indicated that separation for ISAV needed to be in excess of 11km. Norwegian guidelines refer to distances of 2.5km or 5km depending on the size of the farms or aquaculture areas.

The above examples illustrate a broad range of distances, highly dependent on the scenario and the pathogen involved. In all cases, it is clear that the ideal separation distances are greater than the separation of Hananui farms (i.e., ~2km or less), in which the size and shape of the proposed farming area is constrained by a range of legislative and environmental considerations (e.g., seafloor & landscape values). However, while it is recognised that having farms developed closer together than some of the distances indicated above is not ideal, it is also clear that there is no one 'correct' separation distance; it depends on many variables. Ideally, farms should be separated by as great a distance as can be practically achieved. We may determine that one distance offers inherently more attenuation of pathogen in the water column than another, but given the geography of New Zealand and the location of suitable salmon farming sites, it is not possible to set separation distances that would be effective for all pathogens in all situations.

Additionally, it is important to recognise that there are many biosecurity measures which have been shown internationally to be as important, if not more important, than a single focus on separation distance. Some measures may be considered almost binary in the benefit of their application, i.e., single year class on every lease, fallowing of all leases, and planned window (i.e., over a limited time period) for stocking of smolt – there are very few pathogen-specific variables to consider; these measures are universally helpful. NTS therefore considers single year classes, farm fallowing and planned stocking windows to be primary management measures. There are also additional biosecurity measures that NTS is building into its Hananui BMP which will reduce risk across a range of pathogens.

International literature has a range of examples of epidemiological studies that identify the relative importance of risk factors and hence the general importance of the biosecurity measures that NTS are incorporating into their BMP. Odds ratios can give an idea of the importance of control measures for a particular risk, as illustrated in Box 2. These examples illustrate that (for ISAV at least) the reduction in risk from ensuring robust smolt health is three times greater than separating farms by a greater distance (i.e., 10x vs 3.7x). Similarly, management of blood water at harvest has a roughly two and half times greater risk reduction than increased farm separation (9x vs 3.7x).

So, while the Hananui farms may practically be limited to a restricted area, many of the biosecurity measures embedded in the BMP are at least as important as separation distance. While separate epidemiological areas would be ideal, they cannot be achieved within the constraints of the Hananui farming area. The comprehensive nature of the biosecurity and fish health management regimes is therefore designed to make up for this lack of separation to as great a degree as possible.

Box 2. Impact of management measures on likelihood of disease outbreak.

The relative risk numbers represent how many times less likely an outbreak is if that specific risk factor is addressed. See notes at bottom for literature sources (1) and disease acronyms (2).

Risk factor	Relative risk[1]
Smolt quality (smolt weight and osmoregulatory readiness)	10x (ISAV)[2], 1.3x (IPNV)
Management of blood water at harvest	9x (ISAV)
Single year class	7.25x (ISAV)
Good husbandry post smolt input	4.5x (ISAV)
Population size	4x (ISAV), 2x (HSMI)
Separation distance 5km cf 1km	3.7x (ISAV), 1.2x (PD, HSMI)
Fallow	3.5x (PD)
Vessel and diver management	3.3x (ISAV)
Daily mortality removal (summer)	3x (ISAV)

1. Literature sources: Hammell & Dahoo (2005) J. Fish Dis. 28: 651-661, Jarp & Karlsen (1997) Dis. Aquat. Org. 28: 79-86, Gustafson et al. (2007) J. Fish Dis. 30: 101-109, Kilburn et al (2012) Aquaculture 368-369: 89-94, Kristoffersen, Jensen & Jansen (2013) Prev. Vet. Med. 109: 136-143, Aldrin et al (2010) Prev Vet Med. 93: 51-61.
2. Disease acronyms: ISAV, Infectious salmon anaemia virus; IPNV, Infectious pancreatic necrosis virus; HSMI, Heart and skeletal muscle inflammation (Reovirus); PD, Pancreas disease (Alphavirus).

4.4 PATHWAY RISK FROM HANANUI DEVELOPMENT AND OPERATIONS

Table 3 summarises potential risk pathways associated with the Hananui proposal, which could arise during farm development and subsequent operations. The proposal does not increase the risk of non-native pests or pathogens entering the waters of New Zealand, due to anthropogenic pathways being within New Zealand. The most significant domestic pathways are connections from external source regions (e.g., other New Zealand ports). Even within the 'Lower South' operational zone defined by AQNZ, vessel or equipment movements could be important. For example, Otago Harbour is part of this zone, and has established populations of the clubbed tunicate *Styela clava*, which is an unwanted organism that has not been reported from Southland.

The assessment below shows that the Hananui proposal involves a small increase in pathway activity relatively to the current movements in the region (e.g., see Fig. 3). However, the Hananui operation has attributes that make these pathways inherently low risk compared to many existing activities, in particular because pathway connections are among existing hubs of activity and lead to no interactions with remote or pristine areas of Southland.

Nonetheless, although Hananui pathways may not significantly add to the regional marine biosecurity risk profile, they involve interactions with a new hub at the proposed farming area. Hence, it is important that they be managed in a way that reduces the risk that harmful organisms are transported from their origin or home port to the proposed farming areas, or vice versa. Some of the key considerations are outlined below. Note that the importance and relative risk from the pathways describe below differs for pests and pathogens. In particular, vessel and equipment movements, and associated biofouling, are widely regarded as being the most important for pests. By contrast, mechanisms for pathogens arise through a variety of pathways, which in order of generally accepted risk are movement of animals (live or dead or parts of), water, equipment, feed, people, and wild animals.

Table 3. Summary of general aquaculture risk pathways potentially associated with the Hananui development, and matters to be addressed as part of the BMP. Although not listed, disease risk due to the movement of people to and from the farm (e.g., farm staff, divers, visitors, contractors) is relevant in all situations and addressed in the BMP. Risk due to interactions with wild animals is covered separately in Section 4.5.2.

Activity	Description	Potential risks to address in BMP
Farm development	Transfer of infrastructure (pens, nets, etc.) for farm development. Movements to farming area of local vessels or possibly specialist external vessels (e.g., for pen anchor deployment).	Source region of equipment, whether deployed topside or in-water, and risk status (e.g., new and clean vs used and potentially contaminated). All vessel-related mechanisms (hull biofouling, residual seawater, sediment, niche areas).
Smolt transfers	Smolt sourced from commercial freshwater salmon hatcheries licensed under the Freshwater Fish Farming Regulations 1983. Possible transport of smolt to farming area via regionally-based or externally-sourced well-boat.	Hatchery fish health and biosecurity status. Fish delivery tankers (smolt trucks), transport of smolt to farm and cleaning and disinfection of vessels/tankers. All vessel-related mechanisms (hull biofouling, residual seawater, sediment, niche areas).
Fish feed	Commercially extruded pellet feed transferred to farming area (e.g., from Bluff)	All vessel-related mechanisms (hull biofouling, residual seawater, sediment, niche areas).
Fish harvest	Harvested fish and blood water transfer from farming area to Bluff for processing or waste disposal using specialized dead-haul vessel.	Equipment contamination. Secure transport and processing of fish, and disposal or blood water. All vessel-related mechanisms (hull biofouling, residual seawater, sediment, niche areas).
Mortalities	Removed from the pens daily where feasible (and not less than twice per week), using air uplift systems and transported to Bluff for disposal.	Biosecure transport and disposal of dead fish or body parts. All vessel-related mechanisms (hull biofouling, residual seawater, sediment, niche areas).
Personnel transport	Daily movement of water taxis and staff from Oban and/or Bluff.	All vessel-related mechanisms (hull biofouling, residual seawater, sediment, niche areas).
Diving operations	Regular movement of dive boats, divers and associated equipment from Oban and/or Bluff for farm maintenance, defouling, etc.	Dive suits and other dive equipment. All vessel-related mechanisms (hull biofouling, residual seawater, sediment, niche areas).
Net cleaning operations	Vessels used to base net cleaning equipment on, move between pens and farms	Gear movement and vessel movement.
General solid waste		Biosecure containment, transport and disposal. All vessel-related mechanisms (hull biofouling, residual seawater, sediment, niche areas).

Stock movements

Stock movements include smolt used to stock farms, harvested fish, and fish mortalities. Smolt are expected to be sourced from land-based freshwater hatcheries and transported by road to Bluff, then possibly by a specialist 'well-boat' to the farming area. Harvested fish and mortalities will likely be transported to Bluff for processing and/or disposal.

Biosecurity risk can be adequately managed by ensuring appropriate measures are in place for hatchery operations, ensuring the health of the fish stock, and through biosecure transport of fish for processing or disposal of mortalities.

Infrastructure and equipment movements

Development and operation of the farming area will include the following:

- The installation of submerged infrastructure for farm development (i.e., pen anchors, etc.).
- The routine movement of equipment for farm operations such as gear for fish harvest, management of mortalities, and diving operations.

Although details are not yet known, the most important consideration is that the movement of such materials does not introduce new regional risks. For example, used equipment transported from distant locations for permanent (or long-term) in-water deployment in the farming area, could lead to the spread of harmful organisms. Even gear that is only briefly in contact (e.g., for a matter of days) with infected water in a source region has the potential to be a pathway of spread to other locations (Forrest & Blakemore 2006; Schimanski et al. 2016).

To minimise one-off or intermittent risks due to infrastructure and equipment movements, as well as to address risk from routine operations, it is important that equipment (unless new) is treated (i.e., cleaned and disinfected) before being transported to or from the farming area, to mitigate the risk of spreading potentially harmful organisms.

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 smolt stocking, harvest operations, net cleaning and transfer of fish mortalities, blood water and general waste for biosecure disposal.

Table 3 shows that vessels involved in farm development and operations will likely be based mainly in Bluff and/or Oban. These locally-operating vessels are inherently low risk in that any associated harmful organisms that are associated (e.g., as hull biofouling) are likely to be already established regionally (especially in Bluff). As such the BMP focus is to ensure that these vessels are subject to management measures that are reasonable and appropriate in the context of the existing regional risk profile. For example, biofouling measures include standards to ensure that potential biofouling pests (i.e., Table 1) are not spread by vessels, nor invertebrate species that could harbour disease agents such as *Bonamia* spp.

By contrast, specialist vessels from out of the region (and from other AQNZ management zones) may be used at times. For example, farm mooring deployment could require specialist vessels from Nelson or Marlborough. Such movements would presently be subject to management measures stipulated in the *Bonamia ostreae* CAN (described in Section 3.3), but ongoing risk (i.e., in the event the CAN is lifted) will need to be addressed in the BMP.

For example, the Top of the South region has designated harmful organisms than do not occur in Southland and also has range of other species that are potentially problematic despite having no formal status as being harmful (Morrisey & Miller 2008; Forrest et al. 2014).

For species that are not yet present in Southland, minimising the risk of spread from distant source regions provides the best line of defence for marine biosecurity (i.e., prevention is easier than cure). Accordingly, the BMP prescribes management measures for external vessels and equipment (e.g., hull biofouling standards) that are more stringent than for locally-operating vessels.

Note that the risk profile of vessels relates not only to their geographic area of activity, but also to their operational profile. In relation to biofouling, for example, fast-moving vessels typically used for personnel transport are likely to be in regular use, and physical shear forces at high speeds are expected to prevent the accumulation of biofouling. As noted above, this situation contrasts with vessels such as barges that spend long periods idle or move slowly and can therefore be high-risk in terms of biofouling. In this respect, it is relevant to note that the feed barge associated with farming operations will function primarily as a working platform rather than an active vessel; however, it may occasionally be defouled on site by divers and travel to Bluff for maintenance.

4.5 GENERIC FARM-SCALE RISKS

At the farm scale, biosecurity risk can arise in a number of ways even if Hananui risk pathways are effectively managed. Harmful organisms could:

- Establish in the farming area by spread from adjacent established populations, or via wildlife conveyors such as birds or wild fish.
- Proliferate in the farming area environment, or spread among farms within the farming area.
- Be spread to or from the farming area by anthropogenic pathways unrelated to Hananui.

Below we consider these matters for pests and pathogens separately.

4.5.1 Farm-scale marine pest risks

Biofouling

Suspended finfish farm structures provide novel off-bottom habitats that can enable biofouling species, often including non-native species, to reach high densities. Different substratum types (e.g., rope, chain, collars) and orientations (e.g., vertical and horizontal surfaces) provide habitats that suit different species to different degrees (Glasby 2000; Glasby et al. 2007; Ruiz et al. 2009; Fitridge et al. 2012).

The Hananui farming area is in a location where there are existing populations of biofouling organisms that are likely to act as reservoirs for the colonisation of farm structures. Sources include inshore coastal rocky habitats and ecologically significant biogenic habitats in the wider farming environs, which contain typical biofouling taxa such as bryozoans, sponges, calcareous tubeworms, ascidians, anemones, hydroids, bivalves (including flat oysters) and seaweeds. As such, the farm structures are likely to develop biofouling assemblages that resemble the local species pool.

In the same way that the local species pool will influence what grows on farm structures, in the event that a potentially harmful marine pest established and proliferated as part of farm biofouling, the farm could act as a reservoir for spread to the natural environment. From a biosecurity perspective the most significant risk would be the establishment on-farm of a new harmful organisms that did not already exist regionally, again highlighting the fundamental importance of effective pathway management as the first and best line of defence.

Nonetheless, the possibility of a harmful organism establishing, despite pathway management, cannot be discounted, although whether high-density infestations would develop is uncertain. Most examples describing marine pests proliferating on suspended marine farms are from sheltered near-shore environments. The Hananui farming area is in a high energy position with significant wave exposure and moderate currents, and the few New Zealand examples where biofouling has been documented in high-energy environments suggest that 'hard' fouling species such as bivalves and barnacles tend to dominate (Hopkins & Forrest 2010; Atalah et al. 2016; Forrest & Zaiko 2016).

As a precautionary approach it should be assumed that the establishment of new pest species on a Hananui farm structure could facilitate spread to the surrounding seabed environment (e.g., via dispersal of larvae, spores, or dislodged viable fragments), and also lead to spread among Hananui farms. In a way analogous to that described in Section 4.3 for the inter-farm transmission of pathogens, the spatial scale and time-frame of pest spread depends on factors such as hydrodynamics (i.e., water current direction and speed), the density and competency period of propagules (e.g., larvae) in the water column, and survival in the recipient habitat.

For any harmful pest species that established on-farm, the ideal management response would be complete elimination where feasible, or suppression to remove individuals before they became reproductive, thereby minimising the risk of spread beyond the farm environment. Although elimination may not be feasible due to the constraints imposed by an open water marine environment, suppression will be achieved by routine and targeted on-farm operational procedures, in part driven by the need to manage biofouling to a low level to reduce impacts such as described in Section 3.1, including:

- Minimise drag on infrastructure, which in a high energy environment will be essential for the integrity of the farm structures and moorings.
- Minimise the potential role of filter-feeding biofoulers as reservoirs for parasites and pathogens (see Section 4.5).
- Minimise the load of potential stinging biofoulers such as anemones and hydroids, whose role in causing skin lesion in farm fish has been linked to secondary disease (Atalah et al. 2013; Atalah & Smith 2015).
- Maintain water flow through growing nets to keep dissolved oxygen levels high, flush farm wastes, and maintain high water quality. Maintaining a high-quality growing environment reduces stress on farmed finfish and thus reduces their susceptibility to disease.

The need to maintain water flow by regular net cleaning means that harmful organisms would be unlikely to establish on the net surface. Furthermore, based on a Norwegian study, maintaining growing nets largely free of fouling would alone address ~75% of the fouled surface area of farm infrastructure (Bloecher et al. 2015). Additional management to reduce the accumulation of fouling (including target pests) on supporting infrastructure such as net pen collars and mooring lines would be expected to greatly reduce the overall fouling reservoir, thereby minimising the risk of spread to the wider environment. However, in the absence of tools that make it feasible to maintain structures completely free of biofouling, some residual risk will remain. Additionally, for some species (e.g., those that can reattached by fragments) the dislodgement of defouled material to the seabed may also exacerbate local establishment (Floerl et al. 2016).

Environmental changes promoting marine pests

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 organic enrichment and associated faunal changes in sediments beneath and adjacent to pens (Forrest et al. 2007; Keeley et al. 2014).

These types of environmental disturbances are recognised factors that can contribute to the invasion or proliferation of non-native species (Piola & Johnston 2008). For example, the non-indigenous 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). In the Hananui situation, this type of effect is expected to be of minor ecological significance due to the relatively localised nature of the main enrichment footprint.

Other potential mechanisms for pest enhancement also exist, but are poorly understood, and include:

- Deposition of biofouling from farm structures leading to localised attraction of species already established (e.g., predators or scavengers that feed on deposited biofouling).
- Water column enrichment with particulate organic matter or dissolved nutrients has the potential to enhance locally established populations of pests (e.g., of *Undaria* on farm structures).

While these types of effects are possible, they are expected to be highly localised and therefore not of any particular ecological concern.

4.5.2 Farm-scale pathogen risks

To manage farm-scale disease and the risk of pathogens moving off the farms, NTS is implementing a range of measures, including: ensuring good fish husbandry and management, checking the fish daily and monitoring them for disease (as required), protecting them from predators, and ensuring optimum nutrition. Hence, the likelihood of fish becoming diseased and releasing pathogens into the water column is greatly reduced, and in this manner the risk of release of pathogens from the farm in the water column is mitigated.

Even when pathway risks (e.g., stock sourcing, vessel hygiene, equipment cleaning and disinfection) are well-managed, disease can still emerge within farming systems. This reflects the complex interplay between the farm environment, husbandry practices, the host, and surrounding ecosystems. Several recurring drivers are noted across the literature:

- Environmental and operational stressors: Intensive production can amplify stress in stock through high densities, suboptimal water quality, and fluctuating environmental conditions. Stress impairs immune response, increasing susceptibility to pathogens already present at low background levels (Nowak 2007).
- Biofouling as a reservoir: As noted above, biofouling on nets, cages, and other submerged structures can harbour pathogens or their intermediate hosts. Crustaceans and molluscs associated with farm biofouling can play roles in some pathogen life cycles (Krkošek et al. 2011). Fouling communities provide shelter and nutrients for bacteria, parasites, and filter feeders that can vector disease. Cleaning operations may temporarily release concentrated pathogens into the water column (Bloecher et al. 2018) so it is important to manage fouling often and early.
- Wildlife interactions: Farms are open systems that attract or intersect with wild species, with key considerations being:
    - Wild fish aggregation – Structures, shading and waste feed act as fish-aggregation devices. Numerous studies (e.g., Dempster et al. 2002; Dempster et al. 2009) document increased wild fish densities around farms, which can serve as reservoirs or vectors for pathogens.

- Seabirds and mammals – Birds may feed on waste or directly on penned fish, while marine mammals interact with net pens. Both can mechanically transfer pathogens (Murray et al. 2011).

- Waste feed and organic enrichment: Excess feed and faecal material accumulate beneath and around farms, altering benthic communities and attracting scavengers. These nutrient-rich conditions can support pathogen persistence (Brooks & Mahnken 2003).

Mitigation measures, including precision feeding regimes, farm fallowing, mortality removal, cleaning regimes, vaccination, health surveillance, net cleaning and exclusion netting for birds, reduce but rarely eliminate these pressures. Disease emergence often reflects multiple factors acting together rather than a single failure point.

4.5.3 Farm-scale interactions with anthropogenic pathways unrelated to Hananui

A previous Hananui biosecurity assessment (Morrisey 2019) indicated that despite the regional connectivity by vessel pathways (see Fig. 3), most vessels travelling through Foveaux Strait do not come closer than 10km to the farming area. The main exception is the ships using the anchorages described in Section 3.2. Also, it is likely that vessels not represented in Fig. 3 (i.e., those lacking tracking systems, which include most recreational boats) may interact with the Hananui farm.

For example, marine farms can provide focal points for recreational fishing due to wild fish attraction to farm structures or the wider environment (e.g., attraction to fish feed or biofouling deposits on the seabed). This situation raises the potential for interactions between the farming environment and anthropogenic activities unrelated to Hananui, which could exacerbate the spread of harmful organisms (i.e., into or away from the Hananui farming area). Such a risk could arise via mechanisms described in previous sections (e.g., ballast or bilge water discharge, sediment from anchors, biofouling), as well as other potential mechanisms related to specific activities (e.g., pathogen transfer to the farm from recreational fish, bait or shellfish discards).

4.6 ORGANISM-SPECIFIC PATHOGEN RISK ASSESSMENT

The pathogen risk assessment described in Appendix 1 was undertaken to identify, assess, and identify mitigation needs for risks associated with introducing or amplifying aquatic diseases as a result of the proposed Hananui development (Appendix 1). The methodology followed five key steps: hazard identification, risk assessment, risk estimation, risk mitigation, and risk communication. Hazard identification involved screening a wide range of potential pathogens. Risk assessment considered the likelihood of release, exposure, and consequences. Risk estimation combined likelihood and consequence ratings against an Acceptable Level of Protection (ALOP). Hazards exceeding this threshold were carried forward to risk mitigation planning, with the outcomes documented here.

Screening for potential hazards

During the initial screening process, a total of thirty-three potential hazards (i.e., risk species or higher taxa groups) were identified across three categories:

- Viruses (2) – including aquatic birnavirus in salmon and a herpes-like virus in oysters.
- Bacteria (11) – nine associated with salmon (e.g., *Piscirickettsia* spp., *Yersinia ruckeri*, *Vibrio* spp.) and two with oysters (intracellular bacteria and *Vibrio* spp.).
- Parasites (20) – including *Myxobolus cerebralis*, *Caligus longicaudatus*, *Paramoeba/Neoparamoeba*, and oyster parasites such as native *Bonamia exitiosa* and non-native *Bonamia ostreae*.

Most of these organisms were excluded from detailed assessment, either because they are already ubiquitous in New Zealand waters, their complex lifecycles make epidemic outbreaks unlikely, or their incremental risk to the environment was judged to be negligible. From the original list of thirty-three potential hazards, four were retained for detailed assessment due to potential for adverse impacts on salmon aquaculture or the wider environment, as follows:

- Aquatic birnavirus – usually subclinical in salmon but potentially pathogenic to wild fish species.
- *Bonamia* spp. (*B. exitiosa* and *B. ostreae*) – protozoan parasites of flat oysters, with *B. ostreae* representing a serious threat to the Bluff oyster fishery as already noted.
- *Caligus* spp. (sea lice) – marine ectoparasites with the potential for amplification in farms but historically low impacts on Chinook salmon in New Zealand.
- *Piscirickettsia* spp. (NZ-RLO strains) – responsible for significant mortality in salmon aquaculture in New Zealand and overseas.

Key findings and implications of organism-specific pathogen assessment

For the four organisms subject to detailed risk assessment, the following conclusions were reached, with detail in Appendix 1:

- Aquatic birnavirus – overall negligible risk; no mitigation required.
- *Piscirickettsia* spp. – risk rated 'low', above ALOP; mitigation is necessary.
- *Caligus* spp. – negligible risk due to Chinook salmon resistance; no mitigation required.
- *Bonamia* spp. – *B. exitiosa* assessed as 'low' risk, *B. ostreae* as 'moderate' risk; mitigation is warranted.

In summary, therefore, of the thirty-three potential hazards identified in the initial stages of the risk assessment, only two genera (*Bonamia* spp. and *Piscirickettsia* spp.) present a non-negligible risk that requires active mitigation. The BMP therefore emphasises prevention, early detection, and adaptive management to keep risks within acceptable levels. An overview of the specific mitigation considerations for *Bonamia* spp. and *Piscirickettsia* spp. is provided in Section 5.2, and is detailed in the BMP (NTS 2025).

4.7 PATHOGEN INTERACTIONS WITH EXISTING AQUACULTURE AND OYSTER FISHERY

The economic importance of aquaculture and the Bluff oyster fishery has been identified as warranting specific consideration in terms of disease risk, with a high-level assessment provided below.

4.7.1 Aquaculture

The existing Sanford salmon farming operation in Big Glory Bay grows fish from smolt to harvest size and holds broodstock within the same epidemiological area of the Bay. Big Glory Bay also contains mussel farms.

The distance, via the water column, between the proposed site and the existing salmon farms is approximately 24km. Fig. 8 shows the residual tidal flow in the area and demonstrates that predominant risk of waterborne transmission from Big Glory Bay is towards the Hananui site (northeast of Garden Point on Fig. 1), rather than away from the proposed farms.

Morrisey et al. (2011) modelled particle dispersion from aquaculture farms in Big Glory Bay and showed that 24-hour dispersion is minimal, with particles remaining within the Bay.

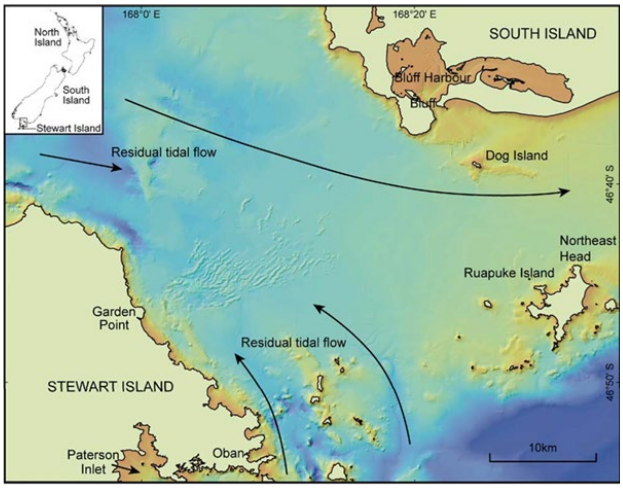


Fig. 8. Tidal current directions in terms of Hananui connectivity with salmon farms in Big Glory Bay (Paterson Inlet) and a proposed farming area east of Ruapuke Island. Adapted from Diggles (2019).

However, the 24-hour modelled duration is relatively short, given that many pathogen propagules have much longer survival times in seawater. Table 4 summarises information on reported dispersal ranges of a variety of pathogens (endemic and exotic) based on international literature. This summary includes the two genera (*Bonamia* and *Piscirickettsia*) assessed in this report as requiring mitigation due to non-negligible risk. From this information, and considering 24km separation to existing salmon farms, it is clear that direct connectivity risk with Hananui via water column dispersal is extremely low. In fact, the only example of a pathogen likely to be capable of direct water column transmission across this spatial scale is the sea lice *Lepeophtheirus salmonis*, which is not present in New Zealand.

4.7.2 Bluff oyster fishery

The Bluff oyster dredge fishery Foveaux Strait is under stress from a number of risk factors including native *Bonamia exitiosa* epidemics, and non-native *B. ostreae* on the Strait's margin (in Big Glory Bay and wider Paterson Inlet). The fishery is recognised as one of the last flat oyster fisheries remaining. As such, while chinook salmon do not act as vectors or reservoirs of bonamiosis, the potential for biofouling on vessels and infrastructure to add to the infection pressure (e.g., leading to transmission to wild seabed oysters from infected oysters in farm biofouling) means that *Bonamia* spp. was subjected to a detailed risk assessment in Appendix 1.

Table 4. Reported dispersal ranges for a variety of endemic and non-native pathogens. Agents non-native to New Zealand are highlighted in light grey, with the remainder being endemic except for *Bonamia* spp. which includes exotic *B. ostreae* and endemic *B. exitiosa*.

Pathogen	Type	Hosts	Environmental persistence	Dispersal distance	Notes
Infectious Salmon Anemia Virus (ISAV)	Virus	Atlantic salmon (highly susceptible); Pacific salmon (resistant)	Hours–days in seawater; >99% inactivation within 48h at 15°C	Typical 1–5km; modeled up to ~0.9km (Ding 2024); risk radius up to 15km (Mardones 2009)	Temperature-sensitive (shorter survival when warm). Most spread occurs between close farms.
Infectious Hematopoietic Necrosis Virus (IHNV)	Virus	Pacific salmon (Chinook, sockeye, etc.); also Atlantic salmon	Days–weeks in cold water; ~7 days at 10°C in freshwater; shorter in seawater	Typical <5km; outbreaks at 2–3km; river–lake system spread ~30km	UV-sensitive; longer persistence at low temp.
Aquatic birnavirus (Proxy = Infectious Pancreatic Necrosis Virus (IPNV))	Virus	Atlantic salmon, trout fry, Chinook (exp.)	Weeks–months in water/sediments; resistant to temp/disinfectants	Several km to tens of km; risk up to 15km	Highly stable, non-enveloped. Long transport possible with currents.
Salmon Alphavirus (SAV)	Virus	Atlantic salmon, trout (Europe)	1–2 days in seawater; outbreaks at 8–16°C	1–2km typical; spread within same fjord	Enveloped RNA virus, fragile; strong seasonality with cooler waters.
Viral Hemorrhagic Septicemia Virus (VHSV, marine subtype)	Virus	Rainbow trout, Atlantic salmon (exp.); many marine fish	Days–week in cold water; ~3–4 days at 10°C	Up to ~5km between farms	Broad host range; mainly a concern in Europe, not major in Pacific NW salmon farms.
Piscirickettsia spp. (Proxy = *P. salmonis*)	Bacterium	Atlantic, coho, Chinook salmon; rainbow trout	21–30 days at 5°C; negligible >25°C; biofilms extend survival	7.5–10km typical; models suggest <20 km possible	Major salmonid pathogen in Chile. Transmission strongest within 5km.
Renibacterium salmoninarum (BKD)	Bacterium	All salmonids	Hours in raw seawater; up to 21 days in organic matter; persists in mud/freezing	Usually <1km; mostly within same cage/site	No spore stage. Main risk is within farm; farm-to-farm water spread rare.
Vibrio spp.	Bacterium	Salmon, trout, many marine fish	Native marine bacteria; days–weeks outside host; biofilm survival	Difficult to define; practical range <5–10km	Already present in environment; outbreaks linked to conditions not just dispersal.
Aeromonas salmonicida (furunculosis)	Bacterium	Salmon, trout (Atlantic, Chinook, others)	Survives days–2 weeks in seawater (longer in cool/brackish)	1–2km typical; historically spread between farms in sea lochs	Birds/boats important for longer jumps.
Tenacibaculum maritimum	Bacterium	Many marine fish incl. salmon	Persists in marine biofilms; long-term survival on surfaces	<1km; farm-level/local	Biofilm-associated; tends not to plume far.
Lepeophtheirus salmonis (sea louse)	Parasite	Atlantic & Pacific salmon	Free-living planktonic larvae survive 10–20 days; surface distribution upper 5m	Typical 8–12km; up to 30–45km; rare >60–100km	Major farm-to-farm vector; dispersal shaped by currents and temp.
Caligus spp. (sea lice)	Parasite	Salmon & other fish	Free-living larvae survive ~1–2 weeks; faster cycle in warm water	5–15km typical; sometimes further	Reservoir in wild fish populations.
Neoparamoeba perurans (AGD)	Parasite	Atlantic, Chinook, other marine fish	Free-living amoeba; indefinite persistence in seawater/biofilms	Local, within same bay/fjord; typically < a few km	No motile stage; mainly spreads downstream within water body.
Internal protozoa (e.g. *Paranucleospora, Ichthyophonus*)	Parasite	Various salmonids	Spore-forming; survive in tissue/sediment	<1km via water; usually within farm	Transmission by ingestion, not drift.
Bonamia spp. (oyster parasite)	Parasite (regional example)	Flat oysters (*Ostrea* spp.)	Short persistence (days) as waterborne cells	Kilometers within bays; tens of km with tidal currents	Not a salmon pathogen, but shows shellfish farm dispersal dynamics.

The assessment identified a 'moderate' release and exposure likelihood for both of the *Bonamia* species, with a high consequence resulting from unmitigated amplification of parasite infectious stages. As such, it is necessary to implement mitigation measures in the form of targeted biofouling management on the farm, so as to limit the number of sexually mature fouling flat oysters, which represent the predominant risk for *Bonamia* spp. transmission. With the implementation of the range of risk mitigations detailed in the pathogen risk assessment, the risk is considered to be reduced below the ALOP of very low.

Bluff oyster dredging is a signifant fishery in Foveaux Strait (source: www.gettyimages.co.nz).

4.8 SIGNIFICANCE OF HANANUI RELATIVE TO THE STATUS QUO

Contextual information in Section 3 on existing risk organisms, pathways, and marine biosecurity management reveals a relatively high level of existing risk for which regional and national management is limited. Except for AQNZ standards and *Bonamia* CAN restrictions on the aquaculture industry (for which compliance and efficacy are unclear), there are no comprehensive pathway management measures in place for Southland that are directly relevant to Hananui.

The wider project area is therefore subjected to ongoing risk from activities with the potential to introduce new harmful organisms. Of particular relevance in the Hananui context are vessel movements into Bluff from external sources nationally and internationally, and any domestic pathways into Oban and elsewhere in Rakiura, such as into Big Glory Bay. Marine biosecurity risk from Hananui cannot therefore be considered in isolation, but is additive to this existing situation. This contextual framework was represented generically for pests and pathogens in Fig. 2 (see Section 2). Box 3 below provides a more detailed illustration for pathogens specifically.

The existing and historical regional risk, in the absence of effective management, is exemplified in Table 5 for some potentially high-risk pests or pathogens, most of which are already present in Southland or in the wider AQNZ Lower South zone that also includes Otago. Table 5 shows that between a species first being detected in New Zealand and the first record in the Lower South zone, the elapsed time ranges between 2 to 23 years. Although separate incursions of some of these established organisms could have arisen from international sources, it is far more likely that they have been spread by domestic anthropogenic activities (e.g., vessel movements from other New Zealand ports).

Table 5. Timing of the first record[1] of high-risk species in the AQNZ Lower South zone (Southland and Otago) compared with first detection in New Zealand, where known.

Species	First NZ record	First southern record (years to incursion)
Pests		
Undaria pinnatifida (Asian kelp)	1987, Wellington & Timaru	BGB 1997 (10) Bluff 1999 (8) Fiordland 2010 (23) Otago Harbour 1990 (3)
Styela clava (Clubbed tunicate)	2005, Auckland	Otago Harbour 2009 (4)
Sabella spallanzanii (Mediterranean fanworm)	2008, Lyttelton	Otago Harbour 2019 (11) Bluff 2025 (17)
Didemnum vexillum (carpet sea squirt)	2001, Whangamata & Marlborough	Otago Harbour 2015 (14) BGB 2022 (21)
Pathogens		
Bonamia ostreae (oyster parasite)	2015, Marlborough	BGB 2017 (2)
Piscirickettsia spp. (bacteria)	2017, Marlborough	Not recorded??

1. Marine pest data from MBP (2025), based on limited surveillance. The timing of spread into Southland and Otago may therefore be earlier than indicated. The *Bonamia ostreae* data are from Santoro (2024) and *Piscirickettsia* spp. based on Brosnahan et al. (2017).

Given the pre-existing pathway pressure (e.g., Fig. 3), it is almost certain that harmful organisms established elsewhere in New Zealand will eventually be introduced to Southland. The main exceptions will be any species for which Southland coastal waters are too cold to enable them to complete their life-cycle (e.g., exotic *Caulerpa* species as already noted). Once established in Southland, especially within vessel hubs such as Bluff, existing experience shows that within-region vessel movements and natural dispersal processes are likely to facilitate regional spread – processes clearly illustrated by the long-term spread of the kelp *Undaria*, and more

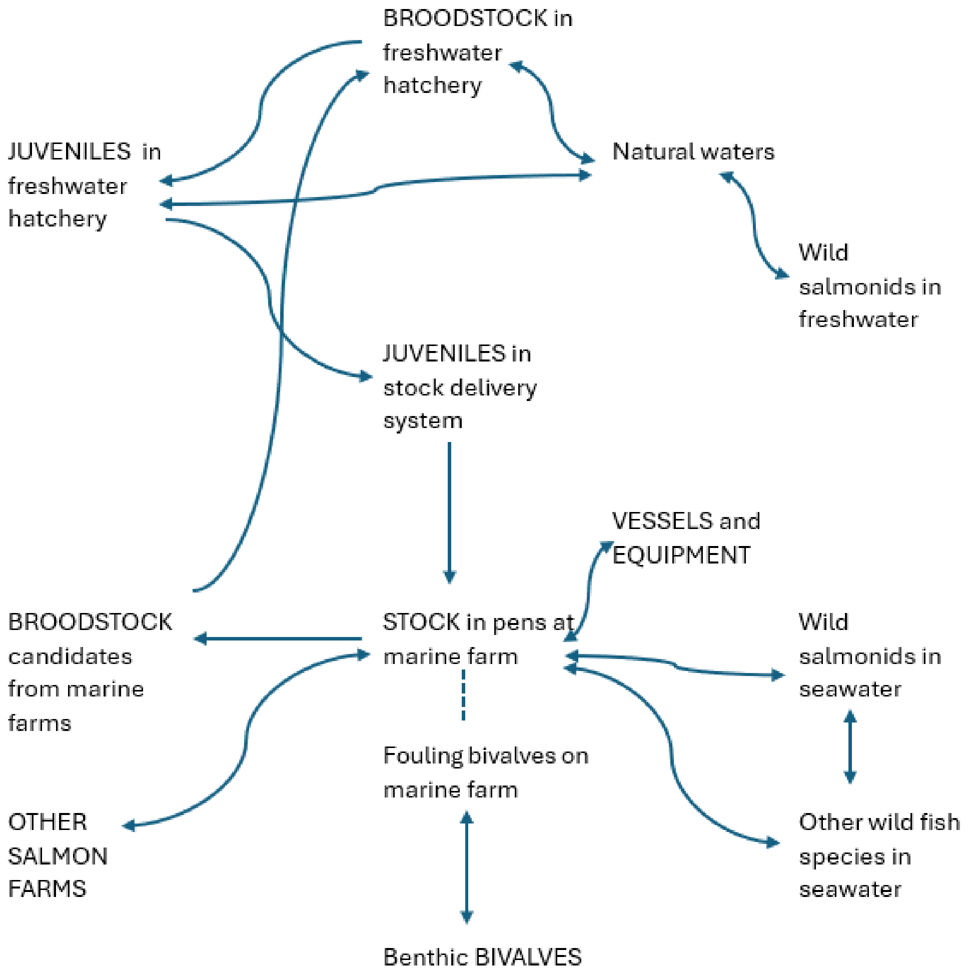
Box 3. Illustration of pathogen pathways, processes and interactions relevant to understanding the incremental disease risk from the Hananui development and operations.

The diagram below shows the primary conceptual pathways by which pathogen risks may arise. In the case of the Hananui proposal, the incremental risks would be:

1. The introduction of a pathogen, not currently present in Southland waters. This could be via juveniles brought into the farm, or via vessels and equipment that have been in contact with aquatic resources outside the Southland area. There are no specific restrictions with respect to aquatic pathogens for non-marine farm vessels and equipment within New Zealand waters.
2. The amplification or multiplication of a pathogen present in the waters around the Hananui farming area, with subsequent release back to the environment at levels higher than might otherwise occur. This process may involve the salmon stock itself, or fouling bivalves on marine farm infrastructure.

The pathways illustrated below reflect both vertical and horizontal transmission; horizontal transmission to/from juveniles in the freshwater environment, and stock on the marine farm to/from wild salmonid and non-salmonid finfish; and potential vertical (true and false) transmission via broodstock returned to freshwater from seawater or exposed to salmonid diseases in a freshwater hatchery.

The pathogen risk assessment (Appendix 1) considered specific organisms and direct measures for risk mitigation that are needed to manage incremental risk from two genera (*Bonamia* and *Piscirickettsia*) identified as having a non-negligible risk. However it is also recognised that there may be unknown risks or cosmopolitan risks that could emerge as an issue if the salmon stock were to be chronically in poor health and welfare condition. With this in mind, the BMP considers generic as well as species-specific measures for biosecurity risk pathways, the requirements for surveillance, and best practice husbandry to ensure that stock are not chronically stressed.



recently by the spread of the parasite *Bonamia ostreae* in Paterson Inlet.

This situation reinforces the primary importance of managing anthropogenic pathway risk, especially from distant source regions from which natural spread to Southland is unlikely to occur. In this existing context, the incremental risk from Hananui is inherently relatively minor, given the existing volume and diversity of unmanaged pathways into and within the region.

By comparison with existing activities, the biosecurity significance of Hananui farm operations is reduced by the following:

- The restricted operating range of most farm-related vessels, noting that movements of these vessels will be in the area around the farm, and existing vessel hubs in Bluff Harbour and possibly Oban.
- There is no interaction with remote or pristine parts of Southland.
- Hananui biosecurity risk is greatly reduced by the range of measures proposed in the BMP (see summary in Section 5.2), which include strict standards for farm-related vessels originating from outside the region, as well as for other risk pathways.

As such, it is highly unlikely that Hananui activities would lead to the spread of new harmful organisms into the region. Rather, it is more likely that farm vessels and equipment would be subsequently exposed to such organisms after they had become established following spread by non-Hananui pathways (for which management is limited) into connected regional hubs (especially Bluff Harbour). That said, Environment Southland is in the early stages of implementing a regional surveillance programme that includes vessel monitoring, and is part of discussions working towards a national pathway management plan. As such, the relative risk from non-Hananui vessels and related pathways may diminish over time.

Accordingly, it is important that effective management measures are in place for the Hananui development. If risk pathways and on-farm biosecurity are managed so that the proposed farming areas do not become reservoirs for harmful organisms, there is an opportunity to protect both the industry operation and the wider environment. Simultaneously, any further development (e.g., by Environment Southland, MPI) of measures that improve regional and national marine biosecurity will add value to efforts by NTS to manage Hananui biosecurity risk.

5. MITIGATION AND RESIDUAL RISK

5.1 OVERVIEW

The BMP that has been prepared for NTS details the measures that will be implemented to mitigate risk (NTS 2025). The BMP includes a suite of management approaches that are largely consistent with AQNZ standards, or are more stringent, and follow MPI's aquaculture biosecurity guidance (MPI 2016) which reflect international best practice. Although some of the BMP detail cannot be finalised until operational activities are known, we are confident that the current document sets a strong foundation for the effective management of risk. To provide further assurance, a recommended requirement is that the BMP is certified by Environment Southland, to ensure that it contains appropriate and effective measures that reflect best-practice biosecurity management.

It is important to reiterate that, despite gradual improvements in regional and national marine biosecurity, risks in Southland arise from many sources unrelated to Hananui. As such, it would be disproportionate and largely futile to impose particularly strict restrictions on a given farming operation such as Hananui if other activities in the area undermine specific management efforts. Simultaneously, it is important to recognise that biosecurity management in the marine environment is particularly challenging by comparison with terrestrial systems, with the most realistic management outcome generally being reduction rather than elimination of risk.

5.2 KEY ELEMENTS OF BMP

5.2.1 BMP Goals

The BMP encompasses the following goals:

1. Pathway management to minimise the likelihood of introducing potentially harmful organisms to the farming area.
2. Surveillance to facilitate early on-farm detection of potentially harmful organisms, including monitoring of fish health.
3. On-farm management of potentially harmful organisms to minimise the risk of further spread, including response to any abnormal clinical presentation of disease in fish.

4. Effective risk management supported by appropriate training, reporting and management systems (e.g., organism identification & response procedures).

The cornerstone of the BMP is the comprehensive management of risk pathways, as this provides the best strategy to address uncertainty and limit the potential for negative flow-on effects (i.e., that could arise due to the uncontrolled incursion of a new harmful organism). Pathway management approaches outlined in the BMP are intended to address risk pathways holistically (e.g., applying generic cleaning and disinfection procedures, minimising hull biofouling). As well as addressing risks from specific organisms, this approach provides the most effective way to address uncertainties regarding potentially problematic organisms that have no designated status as pests or pathogens of concern.

5.2.2 Summary of BMP components

To address the BMP goals, the plan includes pathway and/or on-farm measures that address risks that could arise through movements of farm stock and fish feed, equipment, personnel, vehicles and vessels, as well as on-farm measures relating to biofouling management, wild animal interactions, etc. It also specifies organism-specific risk mitigation measures derived from the pathogen risk assessment process.

Farm stock and husbandry

Stock biosecurity requirements are geared to addressing pathogen risk, and include the following:

- Requirements for the smolt hatchery (e.g., fish monitoring and inspection before transport), and requirements for stock entry to the farms.
- Measures for containment of stock to minimise the risk of fish escapes, and procedures for responding to any escape of fish from the pens.
- On-farm health monitoring of fish, response and contingency planning that describe the procedures in the event of abnormal clinical presentation in fish, mass mortalities, and other scenarios (e.g., jellyfish swarms).
- On-farm water quality monitoring, including of potential harmful microalgae, to ensure a high-quality growing environment.
- On-farm feeding, pen management (e.g., net cleaning) and husbandry measure that are designed to keep fish in optimum health and minimise the risk of disease emergence.
- Procedures for fish harvest and other off-farm stock movements.
- Procedures for sourcing and storage of fish feed.
- Record-keeping of all on- and off-farm stock movements for traceability purposes.

Feed biosecurity

Feed biosecurity requirements are related to processing requirements for the feed to ensure it cannot act as a conveyor of risk organisms. All feed used on the Hananui farms will be commercially produced and heat treated (to contemporary industry processing standards). No 'wet' feed (i.e., whole round fish or unprocessed parts thereof) will be used on the farms.

Equipment

Equipment includes gear associated with the topside of vessels, equipment used on farm, and specialist equipment such as dive gear. Management of equipment movements is particularly important for pathogens, but can be relevant to marine pests in some circumstances (e.g., due to risk from microscopic life-stages and viable fragments of certain pest species, or where biofouling is present). The BMP provides cleaning and disinfection options for these risk pathways (for movement on- and off-farm), and addresses within-farm movements of equipment and divers (e.g., between pens). Among the BMP requirements is a generic measure that equipment brought onto the farm must either be new, or cleaned and disinfected prior to entry. Records of decontamination procedures and activities will be required to be kept in the farm records.

Personnel

The BMP describes farm entry and exit procedures for staff (e.g., regarding hand washing, footwear and clothing), procedures for personnel workflow on-farm, and related requirements for cleaning and disinfection of PPE. Specific requirements for farm visitors are outlined. All of these measures aim to minimise the risk of disease spread with the movement of people.

Vehicles

The BMP describes measures to minimise the risk of pathogen cross-contamination between fish delivery smolt trucks and farm vessels. These include decontamination standards, and measures to be implemented before onloading fish, and for when fish are offloaded into vessel tanks for transport to the farms.

Vessels

Pathogen and pest risk are addressed in relation to:

- Vessel topside mechanisms such as deck areas, with cleaning and disinfection protocols prescribed.

- Residual seawater (e.g., in bilge sumps), for which the BMP requires that such water is not discharged in the farming area or in the Foveaux Strait, except in a safety emergency.
- Vessel anchoring, with a requirement that anchors and ground tackle (e.g., rope and chains) are visibly clean, free of entangled fouling and free of sediment.
- Hull biofouling, which includes measures for target pests as well as potential host organisms for pathogens. The BMP prescribes stringent biofouling standards that minimise the risk of vessels transporting harmful organisms, supported by a verification inspection regime and adoption of best practice hull maintenance.

Targeted pathway and/or on-farm measures for specific pathogens

The organism-specific pathogen risk assessment identified that *Bonamia* spp. and *Piscirickettsia* spp. present non-negligible risks that require active mitigation, as follows:

- For Bonamia spp. mitigation centres on biofouling management. Farms are located over mainly sandy, high-energy benthos, which is not ideal for oyster settlement, consistent with very low oyster densities described in the Hananui benthic surveys. Biofouling removal will be undertaken yearly in winter, timed to remove oysters before they reach maturity and become significantly more risk of release of infectious particles, with autumn monitoring and 'hot-spot' cleaning of high-risk areas such as deep structures and low-flow or shaded areas, particularly where spatfall is noted to have been heavy or pockets of 25-35mm oysters are found on inspection. The winter clean will also assist in removing mussel spat following the end of their settlement period. Monitoring through settlement plates, diver inspections, and molecular testing can allow adaptive management. Biofouling surveillance will be integrated with benthic monitoring, with remedial action available if oyster populations establish beneath the farms.
- For *Piscirickettsia* spp. mitigation focuses on strict hatchery biosecurity, broodstock testing, and disinfection of eggs to reduce the risk of vertical transmission. Routine molecular surveillance will be applied before smolt transfer, combined with veterinary certification. At the farm level, well-flushed waters, stocking density controls, single-year-class cohorts, and fallowing between crops will reduce infection pressure. Biofouling management, stress minimisation, daily (where feasible) mortality removal, and structured health surveillance provide further safeguards. In the event of disease, vaccination (if available) and antibiotic therapies under veterinary direction may be employed.

Targeted on-farm measures for marine pests

Addressing risks from marine pests on farm structures has three main components in the BMP, some of which were described above for *Bonamia* spp. risk management:

- On-farm surveillance for target species and pathogen hosts (flat oysters, other bivalves), which is an embedded part of routine farm operations. The purpose is to facilitate early detection of risk organisms to enable timely interventions.
- Generic on-farm biofouling management, including regular cleaning of nets, and dive inspection and defouling of farm structures, to reduce the risk of farms as a reservoir for harmful organism spread (as well as for maintaining water quality and fish health).
- Response procedures in the event that harmful species are found, noting that eradication may not always be feasible, but that suppression to reduce the risk of further spread can be implemented.

Generic management of wild animal interactions

While the risk is low, birds may represent a conveyor of biosecurity risk and stress in small, farmed fish. It is preferable therefore to prevent direct bird access to the pens, which will be achieved with appropriately fitted and tensioned bird netting.

Although net pen farming systems cannot prevent the entry of wild fish, the use of appropriate mesh size will minimise the entry of larger wild marine fish. Pens and nets will be designed for the expected environmental sea conditions and maintained to preserve their integrity, including net strength testing and regular inspections, to reduce the potential for hole development or net failure and thus mitigate against loss of salmon.

Training, reporting, review and audit

The BMP outlines a range of requirements that involve record keeping, reporting of marine pests and diseases, etc. It also describes Hananui staff training requirements for biosecurity measures. For example, all staff will be trained in recognition of abnormal fish behaviours, clinical presentation of disease, recognition of marine pests, and associated legal obligations and reporting procedures within the Hananui management structure. A specific member of staff will be tasked with managing and monitoring biosecurity compliance with the BMP and biosecurity legislation.

The BMP is designed to be a living document and will be reviewed annually, as well as being amended if there are significant changes to operating or environmental parameters that change the biosecurity risk. Hananui management will carry out random internal audits, at least once per year prior to the review period. The internal audits do not need to encompass the whole BMP and its implementation and operationalisation, but can focus on specific sections.

5.3 USE OF CHEMICAL TREATMENTS FOR RISK MITIGATION

5.3.1 Disinfectants

For biosecurity purposes the farms will use disinfectants as part of the decontamination procedures outlined in the BMP. Disinfection follows thorough washing of surfaces to remove gross organic fouling. This is usually done with copious amounts of seawater pumped through a deck hose on a vessel. Where fouling is more resilient, then biodegradable detergent can be used. Once clean, the disinfectant may be applied. The primary disinfectant to be used is Virkon® Aquatic, a highly effective multi-purpose disinfectant. However, if a situation ever arose where *Piscirickettsia* (RLO) was suspected, then peracetic acid (or peracetic acid/hydrogen peroxide) could be substituted for Virkon® Aquatic. The use of oxidising disinfectants in aquaculture, particularly Virkon® Aquatic and peracetic acid (PAA), has raised attention for potential environmental persistence and non-target toxicity.

Virkon® Aquatic is formulated from potassium peroxymonosulfate (PMPS) combined with organic acids and surfactants. PMPS itself decomposes rapidly to sulfate and oxygen (Block 2001), but the surfactant components are more ecologically relevant. For example, surfactants such as linear alkylbenzene sulfonates exhibit acute toxicity to fish at low mg/L levels, with trout early-life stages especially sensitive (Madsen et al. 2000; Scott & Jones 2000). Chronic exposure studies also show impacts on invertebrates and algae, with sub-mg/L no-effect concentrations indicating that planktonic communities are the critical receptors in near-field discharge zones.

Peracetic acid (PAA) is popular because it decomposes to acetic acid, oxygen, and water, thus avoiding halogenated disinfection by-products (Kitis 2004). In seawater, PAA degrades within minutes to hours depending on temperature and organic matter load (Koivunen & Heinonen-Tanski 2005; Pedersen et al. 2009). Toxicological data indicate that sensitivity varies markedly by species. Freshwater salmonids such as rainbow trout show 96-h LC50 values of ~0.5–0.8mg/L, whereas marine flatfish such as plaice tolerate higher concentrations, with LC50 values around 11mg/L (Pedersen et al. 2009). Zooplankton appear especially sensitive: chronic no-effect concentrations for *Daphnia magna* are reported around 0.01mg/L (Gehr et al. 2003). Even at sub-mg/L levels, residual PAA therefore represents a potential hazard to plankton if dilution is insufficient.

For hydrogen peroxide, acute toxicity thresholds for many marine invertebrates are relatively high (tens to hundreds of mg/L), but sub-lethal endpoints can be more sensitive. Laboratory exposures show copepod feeding is impaired at concentrations around 4mg/L (Straus & Meinelt 2009), highlighting that community impacts may occur at lower levels than outright mortality thresholds suggest.

From a management perspective, the rapid decay of PAA's tends to constrain effects to the immediate discharge zone, whereas the persistence of hydrogen peroxide extends the spatial footprint of risk. Virkon® Aquatic, though less persistent, has chronic toxicity thresholds in the low mg/L to sub-mg/L range for algae and invertebrates. That said, Virkon® Aquatic in Australia has a label condition permitting rinsate (i.e., the treatment water with chemical residue) to enter natural waterbodies. Operational regimes that ensure effluent concentrations fall below ~0.1–0.2mg/L for PAA and ~1–2mg/L for hydrogen peroxide provide a reasonable safety margin relative to known chronic thresholds. In reality, the use of chemical treatments will be intermittent, and compounds entering the water will be dilute and in very low volume. On this basis, it can be expected that effects will be no more than minor and probably not detectable beyond a few metres from the point of use.

5.3.2 Antibiotics

There is no intention to use antibiotics if avoidable. However, if a *Piscirickettsia* spp. was detected and started to produce clinical signs of skin lesions, liver pathology and increased mortality, and especially in the absence of a truly efficacious vaccine, it would be prudent to treat early with an antibiotic to limit establishment opportunity. In this situation the antibiotic of choice would be florfenicol, which is used elsewhere in the salmon industry in New Zealand.

P. salmonis is a bacterial organism that has been identified in the Marlborough area of New Zealand, as well as an apparently non-clinical strain in Akaroa

Harbour. Where the more virulent strains are found it presents a significant challenge to the salmon industry. Good farming practices, strong biosecurity, and proactive vaccinations are all important aspects to disease management. In some situations, antibiotic treatments may be a necessary component to managing outbreaks. Early intervention with responsible use of effective antibiotics can dramatically reduce loss of fish and support fish welfare.

The New Zealand legislation permits veterinarians to use antibiotics in aquaculture settings, and they are only ever used under the direction of a prescribing veterinarian following a thorough investigation. It is possible to apply for permission to import florfenicol via a Special Circumstances Approval Request to the Agricultural Compounds and Veterinary Medicines section of MPI.

Florfenicol is the antibiotic treatment of choice for *P. salmonis* and, as identified by the World Health Organisation, it is not an antibiotic of critical importance to human health. Its key environmental and pharmacodynamic properties are described in Table 6. Florfenicol is widely used in aquaculture around the world (e.g., USA, Canada, United Kingdom, Japan, South Korea, Norway, Chile, China) and has many advantages, for example:

- It is the treatment of choice for *P. salmonis* (Avendaño-Herrera et al. 2023).
- Effective doses are low for florfenicol, meaning relative low quantities of antibiotic can be administered.
- It is highly bioavailable, meaning the vast majority of consumed antibiotic is absorbed by the fish (Martinsen et al. 1993; Pye-MacSwain 1993).
- It does not form strong complexes with calcium and magnesium ions in the seawater, which further improves bioavailability (Jara et al. 2022; Leal et al. 2019).
- It is metabolised quickly by the fish, meaning there are low levels of metabolites excreted, and these are microbiologically inert (Armstrong et al. 2005; Elema et al. 1996).
- It does not adsorb strongly to sediments, nor does it persist for long in sediments (Jara et al. 2022; Pouliquen et al. 1992).
- It displays low toxicity to aquatic organisms (Ferreira et al. 2007; Armstrong et al. 2005).

In Chile, a number of independent studies indicate the susceptibility of *P. salmonis* isolates to florfenicol has remained steady despite widespread use over the years (Avendaño-Herrera et al. 2023; San Martin et al. 2019). Hence, the Chilean data provide evidence that florfenicol resistance has not developed in *P. salmonis* as a result of its use.

5.4 RESIDUAL RISK AFTER MITIGATION

Despite implementation of best practices for marine biosecurity risk mitigation, there remain residual risks due to Hananui that are inherent in aquaculture operations in New Zealand and internationally. The key risks are summarised in Table 7.

Table 6. Key environmental and pharmacodynamic properties of the antibiotic florfenicol (FFC).

Metric	FFC	References	Conclusion
Absorption proportion in fish (absorbed as % of delivered)	96.5-100%	Armstrong et al. 2005; Pye-MacSwain 1993; Pouliquen et al. 1992; Elma et al. 1996	FFC has excellent bioavailability, therefore very small quantities are released into the environment.
Half-life in sediment	4-25 days	Sun et al. 2012; Samuelsen 1989	FFC breaks down quickly in sediments, compared to other common aquaculture antibiotics, e.g., oxytetracycline. FFC is also less likely to partition to the sediment.
Half-life in fish	12-28 hours	Lunestad 2008; Horsberg et al. 1996	FFC is metabolised very quickly in fish. This is why consistent in-feed administration is required.
Half-life in water	30.8 hours (up to 52 at higher doses)	Sun et al. 2012; Jara et al. 2022; Samuelsen 1989	FFC has a short half-life in water. There will also be dispersal and dilution factors involved, so FFC is less likely to persist or be detected in water.
Dose rate	10-20 mg/kg	Arriagada et al. 2024	The dose rate for FFC is substantially lower than for other aquaculture antibiotics, meaning significantly lower quantities can be administered.

Table 7. Summary and comment on residual marine biosecurity risk from Hananui that may arise despite implementation of best practice biosecurity measures.

Residual risk	Issue	Comment
The size of the farming area does not enable epidemiological separation of farms	The proposed farming area is not big enough to achieve hydrodynamic separation of farms, meaning that a pest or disease outbreak in one block could lead to infection of another.	The size of the farming area and location of farms is constrained for various reasons, such as engineering limitations and avoidance of significant ecological values. These constraints do not enable an optimal farm layout for biosecurity management. NTS have adopted the best practical compromise whereby: • The first line of defence is effective pathway management. • Farms are separated along a south-north axis (perpendicular to main water currents) to reduce hydrodynamic connectivity. • Best practice, low stress husbandry, high quality feed and a health surveillance and monitoring programme are implemented to minimise risk.
Fallowing is sequential rather than synchronous	All four farms fallowing simultaneously would enable any disease outbreaks to be mitigated.	It would not be commercially viable to put in place synchronous fallowing across the entire farming area. Hence, each farm will be fallowed in turn. Despite relatively close proximity it has been shown empirically that fallowed farms, accompanied by cleaning processes, can have a very positive effect on pathogen management.
Pathway management fails	Pathway management comprises measures that target visible as well as microscopic organisms or life-stages. For the latter, especially for disease management, the measures may not be 100% effective.	• Risk reduction is the best that can be achieved by pathway management, exemplified by continued international border incursions despite the biofouling, ballast water and sediment standards in place. • The pathway measures proposed in the BMP are more stringent than for other vessels and for many of the consented aquaculture operations in the region. • For disease management, the BMP includes measures such as cleaning and disinfection that are successfully used to manage risk in finfish aquaculture globally.
Harmful organism(s) establish in the farming area	Harmful organisms establish in farming area for reasons beyond NTS control for example: • Non-Hananui vessels around the farming area (e.g., international vessels at nearby anchorages). • Climate change alters the biosecurity risk profile and leads to emergence of new pests or diseases.	In any biosecurity scenario, acceptance of some residual risk is necessary as a zero-risk operation is neither practical nor achievable. Notwithstanding, it is noted that: • Border controls are expected to minimise the risk from international vessels at anchor near Hananui. • The regional risk from anchored ships is probably more significant while they are dockside in Bluff Harbour (i.e., due to sheltered, shallow water and diverse habitats for harmful organisms). • To reduce interactions with non-farm vessels, NTS is proposing an exclusive occupation area around each farm, up to 50 m beyond the edge of the mooring anchors, or to the site boundary where that is less than 50 m. • Climate change has regional implications irrespective of Hananui. However, assuming there is an increased risk of disease emergence with increased seawater temperatures, continency planning for management of unforeseen disease outbreaks has been embedded in the BMP.
Outbreaks of harmful organisms established on-farm may spill over to the wider environment.	Aquaculture occurs in an open water environment in which containment of harmful organism outbreaks cannot be guaranteed.	Despite industry best practice to manage on-farm reservoir and spillover risk, there will remain residual risks that are inherent part of aquaculture operations. Examples include: • It is not feasible to maintain farm structures free of biofouling but it is expected to be feasible to remove visible harmful organisms for land disposal. Other biofouling can be suppressed to levels that minimise the potential reservoir for disease. • Complete capture of all biofouling waste is not operationally feasible - in other New Zealand aquaculture operations, the material defouled from farm structures is not captured. However, regular cleaning of structures and nets as proposed in the BMP will reduce the biomass released in any single cleaning event. • The risk of disease transmission to wild fish populations is low, but cannot be completely mitigated in that small wild fish can access the growing pens. • Waterborne dispersal of harmful organisms from the farming area could infect other anthropogenic activities in the farming environs (e.g., recreational fishing and vessel anchorage). Except for measures in place to manage and contain potentially harmful organisms, these types of interactions cannot be controlled by NTS.
Risk from shared port facilities	Hananui operations will use the same port facilities as other salmon farmers, and other regional, domestic and international vessels, adding to the network within which harmful organisms may be spread.	This issue is a residual risk of all human activity in the marine environment, and is the reason that hubs of vessel activity are 'hotspots' for the initial incursion and subsequent spread of harmful organisms. While exacerbated by Hananui, the increased activity due to the new development is small and inherently low risk; for example, pathways are among existing vessel hubs and lead to no interaction with remote or pristine parts of Southland. Moreover, adherence to strict pathway management measures outlined in the BMP (e.g., cleaning and distinction measures) minimise the risk to/from Hananui.

Some of these residual risks arise from future uncertainty. For example, a warming sea and increasing incidence of marine heatwaves could provide an avenue for the incursion of new pests and pathogens that may not currently be able to establish in New Zealand or the Foveaux Strait area. The review and certification process embedded in the BMP provides a mechanism to ensure that new risks are identified, and management measures are adapted, as the operational risk profile changes. Additionally, by including pathway measures in the BMP that target all organisms irrespective of known status as harmful, the scope for flow-on risk from Hananui is minimised.

6. MATTERS RAISED BY THE EXPERT CONSENTING PANEL

The Expert Consenting Panel that evaluated the consent application under the COVID-19 Recovery (Fast-Track Consenting) Act was satisfied that "*with the imposition of conditions and implementation of a certified BMP, the biosecurity risk of the Proposal is likely to be minor…*". The single exception related to potential disease risk to the Bluff oyster fishery, with the specific issue of concern being risk due to *Bonamia* spp. The Panel accepted that with the implementation of the BMP, the likelihood of introducing disease to the oyster fishery would be low, but nonetheless expressed a belief that the consequences of an introduction "*…could be catastrophic to the survival of the species and the fishery*".

The revisited risk assessment in Appendix 1 defined the likelihood of release and exposure and related consequences. This unrestricted risk assessment (i.e., assuming no mitigation) rated consequence as 'high' based on the potential regionality of the impact. However, due to the proposed mitigation, as well as a change in the regional risk profile since the Panel's decision was released, the risk assessment demonstrated that the incremental *Bonamia* spp. risk from farm biofouling to wild oyster populations is below the ALOP of very low. Some key points that support this conclusion are as follows:

- Flat oysters do not commonly occur in vessel biofouling, and the potential for transport to the farm is naturally very low.
- Flat oyster densities on the seabed in the farming area are very low, but are nonetheless the most likely source of flat oysters that could colonise farm structures.
- Native *Bonamia exitiosa* is already present in flat oysters in the wider Hananui environs, meaning that wild populations are the most plausible source of a farm infection.
- Non-native *Bonamia ostreae* is well-established in Big Glory Bay, and has been assessed by MPI as being likely to naturally spread into Foveaux Strait by 2026-2030, and throughout the oyster fishery within 7-14 years (Santoro 2024).
- The comprehensive on-farm regime for biofouling management is designed to remove flat oysters before they reach size classes that can harbour *Bonamia* spp.

7. CONCLUSIONS

Key conclusions from the Hananui biosecurity assessment in terms of the significance of development effects post-mitigation, are summarised in Table 8, and are as follows:

- With effective management of risk pathways, especially from external source regions, the risk of farm development and operations leading to the introduction and spread of harmful organisms in the Southland region will be no more than minor by comparison with most existing pathways for which management is limited.
- For harmful organisms already established regionally, the proposal may lead to their local establishment in the farming area or wider environs, but a range of mitigation measures are planned by NTS that will greatly reduce risk. These include measures to manage pest and disease risk due to farm biofouling, and a range of measures that optimise fish health, ensure a high-quality growing environment, and thus minimise the likelihood of disease outbreak.
- Despite mitigation through adoption of international best management practices, residual risks are inherent in all open water aquaculture operations across New Zealand (not just Hananui) and internationally, and cannot practically be eliminated. Nonetheless, with an effective BMP the overall incremental effect of the Hananui proposal is assessed as no more than minor.

Table 8. Summary of key marine biosecurity risks from the Hananui proposal, the mitigation required, and the assessed post-mitigation significance. Mitigation measures are detailed in BMP provisions in a separate document. Incremental significance is assessed in the context of the pre-existing situation, for which management is limited.

Key potential risk	Key potential effects	Key mitigation	Incremental significance post-mitigation
PATHWAYS			
Pathways from domestic source regions, especially vessels, introduce marine pests currently absent from region	New marine pest introduced to farm location that could subsequently spread	Management of external vessels and other external pathways, especially in relation to biofouling risk through adherence to strict 'clean hull' standards	**Negligible:** The 'clean hull' standard makes it highly unlikely that harmful species will be present on vessel entry to the region, and is supported by a regime of routine vessel inspection and hull maintenance, as well as other management measures. By comparison, there is limited management of other inter-regional pathways.
Pathways from domestic source regions, especially stock or equipment movements, introduce pathogens currently absent from region	New pathogen introduced into local waters, which could enter a naive wild finfish population	Movement of juvenile salmon from freshwater hatcheries, with biosecurity management and targeted health surveillance. Equipment cleaned and disinfected (or new) before entry.	**Negligible:** Sourcing juveniles from freshwater will eliminate risk of movement of seawater-specific pathogens. Use of hatcheries with biosecurity management plans and health surveillance systems (both targeted and non-targeted surveillance) will reduce the risk of pathogen entry via juvenile stock. Equipment can be thoroughly cleaned and disinfected to eliminate risk.
Regional pathways operating within project area carry established organisms	Incremental spread of organism already established in region	Effective management of regional pathways based on hull biofouling standards, cleaning and disinfection procedures, and other measures	**Negligible to minor:** Pathway management based on international biosecurity best practice will reduce regional risk to level considerably less than existing activities. Farm-related movements are locations already subject to considerable unmanaged pathway pressure.
FARM SCALE			
Reservoir of marine pests establishes on farm and facilitates subsequent spread	Local natural habitats and associated values (e.g. ecological values, fishery resources, natural character) adversely affected	Surveillance for organism, and maintenance of low biofouling levels on farm structures	**Minor:** Biofouling management will greatly reduce on-farm reservoir, but a residual risk remains to biogenic and coastal rocky reef. However, a more significant risk already exists due to regional vessel movements and natural dispersal from established organism populations.
Fouling organisms on farm infrastructure act as amplification reservoirs for mollusc pathogens	Increases infection pressure on the native flat oysters in the Foveaux Strait flat oyster fishery	Scheduled biofouling clearance timed to remove mussel and flat oyster settlement at periods when they are fragile and prior to peak infection intensity and shedding risk	**Extremely low:** By ensuring stock are managed in well-designed farm systems, given nutritious feed, handled carefully, and have an active health management system, stock on the farm are much less likely to become infected with endemic pathogens and express clinical disease, which is when maximal shedding occurs. Combined with a relatively low host density of wild fish outside the farm, the risk of amplification of pathogens in the farm to the point of an adverse effect on wild fish is minimised.
Stock held on the farms act as amplification sources for endemic finfish pathogens	Wild finfish passing or attracted to the farms are exposed to elevated levels of endemic pathogens	Best practice husbandry, management of on-farm stressors, high quality and nutritious feed, and an active animal health surveillance and response system, reduces the likelihood of farmed stock becoming infected at high levels with endemic pathogens and restricts their capacity to shed pathogens	**Extremely low:** By ensuring stock are managed in well-designed farm systems, given nutritious feed designed for the species and life stage, careful handling procedures and an active health management system, the stock on the farm are much less likely to become infected with endemic pathogens and express clinical disease, which is when maximal shedding occurs. When combined with a naturally relatively low host density of wild fish outside the farm, the risk of amplification of pathogens in the farm to the point of an adverse effect on wild fish is reduced to extremely low.

8. REFERENCES CITED

Acosta H, Forrest BM 2009. The spread of marine non-indigenous species via recreational boating: A conceptual model for risk assessment based on fault tree analysis. Ecological Modelling 220(13-14): 1586-1598.

Aldrin M, Storvik B, Frigessi A, Viljugrein H, Jansen PA 2010. A stochastic model for the assessment of the transmission pathways of heart and skeletal muscle inflammation, pancreas disease and infectious salmon anaemia in marine fish farms in Norway. Preventive Veterinary Medicine 93: 51-61.

Anderson L G, White P C L, Stebbing P, Stentiford G D, Dunn A M 2014. Biosecurity and vector behaviour: Evaluating the potential threat posed by anglers and canoeists as pathways for the spread of invasive non-native species and pathogens. PLOS ONE 9(4): e92788.

AQNZ 2023. Greenshell Mussel Industry Biosecurity Standards. Aquaculture New Zealand, September 2023. 35p.

AQNZ 2024a. Pacific Oyster Biosecurity Standards. Aquaculture New Zealand, April 2024. 39p.

AQNZ 2024b. New Zeland Salmon Biosecurity Standards. Aquaculture New Zealand, July 2024. 29p.

Armstrong SM, Hargrave BT, Haya K, Hargrave BT 2005. Antibiotic Use in Finfish Aquaculture: Modes of Action, Environmental Fate, and Microbial Resistance. In Environmental Effects of Marine Finfish Aquaculture (pp. 341–357). Springer Berlin Heidelberg.

Arriagada G, Vásquez F, Montt R, Navarro C 2024. Quantifying antimicrobial consumption in the Chilean salmon industry using standardized metrics and indicators: The case of florfenicol and oxytetracycline. Preventive Veterinary Medicine 233: 106331.

Atalah J, Fletcher LM, Forrest BM 2021. Impacts of a putative invasive ascidian on rocky shore communities. Marine Environmental Research 168: 105308.

Atalah J, Fletcher LM, Hopkins GA, Heasman K, Woods CMC, Forrest BM 2016. Preliminary assessment of biofouling on offshore mussel farms. Journal of the World Aquaculture Society 47(3): 376–386.

Atalah J, Floerl O, Pochon X, Townsend M, Tait L, Lohrer AM 2019. The introduced fanworm, *Sabella spallanzanii*, alters soft sediment macrofauna and bacterial communities. Frontiers in Ecology and Evolution 7(481).

Atalah J, Newcombe E, Hopkins G 2013. Biofouling community composition at three salmon farms in Queen Charlotte Sound. Cawthron Report No. 2396. 10p.

Atalah J, Smith K 2015. Assessment of stinging cells and identity of anemones at Ruakaka Bay salmon farm. Cawthron Report No. 2672. 6p.

Avendaño-Herrera R, Mancilla M, Miranda C D 2023. Use of antimicrobials in Chilean Salmon farming: Facts, myths and perspectives. Reviews in Aquaculture 15(1): 89-111.

Block SS 2001. Disinfection, Sterilization, and Preservation (5th ed.). Philadelphia: Lippincott Williams & Wilkins.

Bloecher N, Floerl O, Sunde LM 2015. Amplified recruitment pressure of biofouling organisms in commercial salmon farms: potential causes and implications for farm management. Biofouling 31(2): 163-172.

Bloecher N, Powell A, Patursson Ø 2018. Biofouling in marine aquaculture: A review of recent research and developments. Biofouling 34(6): 585–598.

Brady D J, Meade R, Reynolds JD, Vilcinkas A, Theissinger K 2024. The crayfish plague pathogen *Aphanomyces astaci* in Ireland. Microorganisms 12(1): 102.

Brooks KM, Mahnken CV 2003. Interactions of Atlantic salmon in the Pacific Northwest environment II. Organic wastes. Fisheries Research 62(3): 255–293.

Brosnahan CL, Ha HJ, Booth K, McFadden AMJ, Jones JB 2016. First report of a rickettsia-like organism from farmed Chinook salmon, *Oncorhynchus tshawytscha* (Walbaum), in New Zealand. New Zealand Journal of Marine and Freshwater Research, 51(3): 356–369.

Castinel A, Fletcher L, Dhand N, Rubio A, Whittington RJ, Taylor M 2015. OsHV-1 mortalities in Pacific oysters in Australia and New Zealand: the farmer's story. Cawthron Report No. 2567. 48p. plus appendices.

Castinel A, Webb SC, Jones JB, Peeler EJ, Forrest BM 2019. Disease threats to farmed green-lipped mussels Perna canaliculus in New Zealand: review of challenges in risk assessment and pathway analysis. Aquaculture Environment Interactions 11: 291-304.

Chambers CB, Ernst I 2005. Dispersal of the skin fluke *Benedenia seriolae* (Monogenean Capsilidae) by tidal current and implications for sea-cage farming of *Seriola* sp. Aquaculture 250(1): 60-69.

Costello KE, Lynch SA, McAllen R, O'Riordan Ruth M, Culloty SC 2021. The role of invasive tunicates as reservoirs of molluscan pathogens. Biological Invasions 23(2): 641-655.

Coutts ADM, Dodgshun TJ 2007. The nature and extent of organisms in vessel sea-chests: a protected mechanism for marine bioinvasions. Marine Pollution Bulletin 54(7): 875-886.

Coutts ADM, Piola RF, Hewitt CL, Connell SD, Gardner JPA 2010a. Effect of vessel voyage speed on survival of biofouling organisms: implications for translocation of non-indigenous marine species. Biofouling: The Journal of Bioadhesion and Biofilm Research 26(1): 1 - 13.

Coutts ADM, Piola RF, Taylor MD, Hewitt CL, Gardner JPA 2010b. The effect of vessel speed on the survivorship of biofouling organisms at different hull locations. Biofouling: The Journal of Bioadhesion and Biofilm Research 26(5): 539 - 553.

CRMS 2023. Craft Risk Management Standard: Vessels. Ministry for Primary Industries, Wellington, New Zealand, 13 October 2023. 8 p.

Darbyson E, Locke A, Hanson JM, Willison JHM 2009. Marine boating habits and the potential for spread of invasive species in the Gulf of St. Lawrence. Aquatic Invasions 4(1): 87-94.

Davidson I, Cahill P, Hinz A, Kluza D, Scianni C, Georgiades E 2021. A Review of Biofouling of Ships' Internal Seawater Systems. Frontiers in Marine Science 8.

Davidson JDP, Landry T, Johnson GR, Quijón PA 2017. A cost-benefit analysis of four treatment regimes for the invasive tunicate *Ciona intestinalis* on mussel farms. Management of Biological Invasions 8: (in press).

Dempster T, Sanchez-Jerez P, Bayle-Sempere J, Giménez-Casalduero F, Valle C 2002. Attraction of wild fish to sea-cage fish farms in the southwestern Mediterranean Sea: Spatial and short-term temporal variability. Marine Ecology Progress Series 242: 237–252.

Dempster T, Uglem I, Sanchez-Jerez P, Fernandez-Jover D, Bayle-Sempere J, Nilsen R 2009. Coastal salmon farms attract large and persistent aggregations of wild fish: An ecosystem effect. Marine Ecology Progress Series 385: 1–14.

Diggles B 2019. Assessment of Environmental Effects – Disease Risk Assessment Report For Proposed Salmon Farms at Stewart Island, New Zealand. DigsFish Services Report: DF 19-02 prepared for Ngai Tahu Seafood Resources, May 2019. 114p.

Ding F, Gagné N, Ditlecadet D, Quinn BK, Trudel M 2024. Modelling the dispersion of infectious salmon anemia virus from Atlantic salmon farms in the Quoddy Region of New Brunswick, Canada and Maine, USA. FACETS 9: 1-19.

Dobbs FC, Goodrich AL, Thomson FK, Hynes W 2013. Pandemic serotypes of Vibrio cholerae isolated from ships' ballast tanks and coastal waters: Assessment of antibiotic resistance and virulence genes (tcpA and ctxA). Microbial Ecology 65: 969–974.

Drake LA, Doblin MA, Dobbs FC 2007. Potential microbial bioinvasions via ships' ballast water, sediment, and biofilm. Marine Pollution Bulletin 55(7-9): 333-341.

Elema MO, Hoff KA, Kristensen HG 1996. Bioavailability of oxytetracycline from medicated feed administered to Atlantic salmon (Salmo salar L.) in seawater. Aquaculture 143(1): 7–14.

Ferreira CSG, Nunes BA, Henriques-Almeida JM de M, Guilhermino L 2007. Acute toxicity of oxytetracycline and florfenicol to the microalgae *Tetraselmis chuii* and to the crustacean *Artemia parthenogenetica*. Ecotoxicology and Environmental Safety 67(3): 452–458.

Fitridge I, Dempster T, Guenther J, de Nys R 2012. The impact and control of biofouling in marine aquaculture: a review. Biofouling 28(7): 649-669.

Fletcher LM 2014. Background information on the Mediterranean fanworm *Sabella spallanzanii* to support regional response decisions. Prepared for Marlborough District Council. Cawthron Report No. 2479A. 35 p.

Fletcher LM, Forrest BM, Bell JJ 2013. Impacts of the invasive ascidian *Didemnum vexillum* on aquaculture of the New Zealand green-lipped mussel, *Perna canaliculus*. Aquaculture Environment Interactions 4: 17-30.

Fletcher LM, Zaiko A, Atalah J, Richter I, Dufour CM, Pochon X, Wood SA, Hopkins GA 2017. Bilge water as a vector for the spread of marine pests: a morphological, metabarcoding and experimental assessment. Biological Invasions 19(10): 2851-2867.

Floerl O, Sunde LM, Bloecher N 2016. Potential environmental risks associated with biofouling management in salmon aquaculture. Aquaculture Environment Interactions 8: 407-417.

Forrest B 2018. Regional recreational vessel fouling and marine pest survey 2017/18. Technical Report 2018/01, Top of the South Marine Biosecurity Partnership, Nelson, June 2018. 32 p.

Forrest B, Cahill P, Newcombe E, Taylor D 2014. Marine pests and management concepts for shellfish aquaculture. Prepared for the Ministry of Business, Innovation and Employment Contract CAWX0802. Cawthron Report No. 2285. 39 p. plus appendices.

Forrest B, Fletcher L 2015. Managing biosecurity risk pathways in shellfish aquaculture: options for biofouling. Prepared for the Ministry of Business, Innovation and Employment Contract CAW1315. Cawthron Report No. 2642. 22 p. plus appendix.

Forrest B, Keeley N, Gillespie P, Hopkins G, Knight B, Govier D 2007. Review of the ecological effects of marine finfish aquaculture. Prepared for the Ministry of Fisheries. Cawthron Report No. 1285, Cawthron Institute, Nelson, New Zealand. 73p. + Appendices.

Forrest B, Zaiko A 2016. Marine biosecurity risks from offshore Māui facilities. Cawthron Report 2812, June 2016. 66p plus appendices.

Forrest BM, Atalah J 2017. Significant impact from blue mussel Mytilus galloprovincialis biofouling on aquaculture production of green-lipped mussels in New Zealand. Aquaculture Environment Interactions 9: 115-126.

Forrest BM, Blakemore KA 2006. Evaluation of treatments to reduce the spread of a marine plant pest with aquaculture transfers. Aquaculture 257: 333-345.

Forrest BM, Brown SN, Taylor MD, Hurd CL, Hay CH 2000. The role of natural dispersal mechanisms in the spread of *Undaria pinnatifida* (Laminariales, Phaeophyta). Phycologia 39: 547-553.

Forrest BM, Creese RG 2006. Benthic impacts of intertidal oyster culture, with consideration of taxonomic sufficiency. Environmental Monitoring and Assessment 112: 159–176.

Forrest BM, Hopkins GA 2013. Population control to mitigate the spread of marine pests: insights from management of the Asian kelp *Undaria pinnatifida* and colonial ascidian *Didemnum vexillum*. Management of Biological Invasions 4(4): 317-326.

Forrest BM, Stevens LM 2024. Waipapa Point Intertidal Rocky Shore Survey 2024 and Comparison to Baseline Surveys 2011-2013. Salt Ecology Report 143, prepared for Environment Southland, July 2024. 36p.

Forrest BM, Taylor MD 2002. Assessing invasion impact: survey design considerations and implications for management of an invasive marine plant. Biological Invasions 4(4): 375-386.

Frey MA, Simard N, Robichaud DD, Martin JL, Therriault TW 2014. Fouling around: vessel sea-chests as a vector for the introduction and spread of aquatic invasive species. Management of Biological Invasions 5(1): 21-30.

Fuhrmann M, Georgiades E, Cattell G, Brosnahan C, Lane HS, Hick PM 2021. Aquatic pathogens and biofouling: pilot study of ostreid herpesvirus 1 translocation by bivalves. Biofouling 37(9-10): 949-963.

Gehr R, Wagner M, Veerasubramanian P, Payment P 2003. Disinfection efficiency of peracetic acid, UV and ozone after enhanced primary treatment of municipal wastewater. Water Research 37(19): 4573–4586.

Georgiades E, Scianni C, Davidson I, Tamburri MN, First MR, Ruiz G, Ellard K, Deveney M, Kluza D 2021. The Role of Vessel Biofouling in the Translocation of Marine Pathogens: Management Considerations and Challenges. Frontiers in Marine Science 8(435).

Glasby TM 2000. Surface composition and orientation interact to affect subtidal epibiota. Journal of Experimental Marine Biology and Ecology 248(2): 177-190.

Glasby TM, Connell SD, Holloway MG, Hewitt CL 2007. Nonindigenous biota on artificial structures: could habitat creation facilitate biological invasions? Marine Biology 151(3): 887-895.

Gnanalingam G, Hepburn CD 2019. Control of *Undaria pinnatifida* in Breaksea Sound, Fiordland. Prepared for Environment Southland. Envirolink Grant: 1919-ESRC290. 66p.

Green DM 2010. A strategic model for epidemic control in aquaculture. Preventive Veterinary Medicine 94: 119-127.

Heasman K, de Zwart E 2004. Preliminary investigation on *Amphisbetia bispinosa* colonisation on mussel farms in the Coromandel. Prepared for NZMIC. Cawthron Report 928. 7 p.

Hewitt CL, Gollasch S, Minchin D 2009. The vessel as a vector – biofouling, ballast water and sediments. In: Rilov G, Crooks JA ed. Biological Invasions in Marine Ecosystems: Ecological, Management, and Geographic Perspectives. Berlin Heidelberg, Springer. Pp. 117-131.

Hewitt CL, Willing J, Bauckham A, Cassidy AM, Cox CMS, Jones L, Wotton DM 2004. New Zealand marine biosecurity: delivering outcomes in a fluid environment. New Zealand Journal of Marine and Freshwater Research 38(3): 429-438.

Hopkins G, Davidson I, Georgiades E, Floerl O, Morrisey D, Cahill P 2021. Managing Biofouling on Submerged Static Artificial Structures in the Marine Environment – Assessment of Current and Emerging Approaches. Frontiers in Marine Science 8(1507).

Hopkins GA, Forrest BM 2010. A preliminary assessment of biofouling and non-indigenous marine species associated with commercial slow-moving vessels arriving in New Zealand. Biofouling: The Journal of Bioadhesion and Biofilm Research 26(5): 613 - 621.

Horsberg TE, Hoff KA, Nordmo R 1996. Pharmacokinetics of florfenicol and its metabolite florfenicol amine in Atlantic salmon. Journal of Aquatic Animal Health 8(4): 292-301.

Hunt L, Chadderton L, Stuart M, Cooper S, Carruthers M 2009. Results of an attempt to control and eradicate *Undaria pinnatifida* in Southland, New Zealand, April 1997 - November 2004. Department of Conservation, Invercargill, New Zealand. 48p.

IMO 2004. The International Convention for the Control and Management of Ships' Ballast Water and Sediments. BWM/CONF/36. Pp. 38.

Inglis G, Gust N, Fitridge I, Floerl O, Woods C, Hayden B, Fenwick G 2005. Port of Bluff baseline survey for non-indigenous marine species (Research Project ZBS 2000/04). Prepared for BNZ Post-clearance Directorate, Biosecurity New Zealand Technical Paper No: 2005/09. 57p plus appendices.

Inglis G, Morrisey D, Woods C, Sinner J, Newton M 2013. Managing the Domestic Spread of Harmful Marine Organisms Part A: Operational Tools for Management. MPI Technical Paper No: 2013/xx. A report prepared for the Preparedness & Partnerships Directorate. Ministry for Primary Industries Wellington.

Inglis GJ, Floerl O, Ahyong S, Cox S, Unwin M, Ponder-Sutton A, Seaward K, Kospartov M, Read G, Gordon D, Hosie A, Nelson W, d'Archino R, Bell A, Kluza D 2010. The biosecurity risks associated with biofouling on international vessels arriving in New Zealand: summary of the patterns and predictors of fouling. Biosecurity New Zealand Technical Paper No: 2008. A report prepared for MAF Biosecurity New Zealand Policy and Risk Directorate Project FP0811321 No. 182. 168 p.

James K 2016. A review of the impacts from invasion by the introduced kelp Undaria pinnatifida. Waikato Regional Council Technical Report 2016/40. 40p.

Jara B, Srain BM, Aranda M, Fernández C, Pantoja-Gutiérrez S, Méjanelle L 2022. Water-sediment partitioning of flumequine and florfenicol, two antibiotics used in salmon aquaculture in Chile. Marine Pollution Bulletin 177: Article 113480.

Jeffs A, Stanley J 2010. The occurrence of barnacles on Coromandel mussel farms: a preliminary report for Sealord Shellfish Ltd. Leigh Marine Laboratory, The University of Auckland. 7p.

Keeley N, Gillard M, Broekhuizen N, Ford R, Schuckard R, Urlich S 2014. Best Management Practice guidelines for salmon farms in the Marlborough Sounds: Benthic environmental quality standards and monitoring protocol. Prepared by the Benthic Standards Working Group, November 2014.

Keeley NB, Macleod CK, Forrest BM 2012. Combining best professional judgement and quantile regression splines to improve characterisation of macrofaunal responses to enrichment. Ecological Indicators 12: 154-166.

Kitis M 2004. Disinfection of wastewater with peracetic acid: a review. Environment International 30(1): 47–55.

Koivunen J, Heinonen-Tanski H 2005. Peracetic acid (PAA) disinfection of wastewater at low temperatures. Water Research 39(18): 446–452.

Krkošek M, Ford JS, Morton A, Lele S, Myers RA, Lewis MA 2011. Fish farms, parasites, and predators: Implications for salmon population dynamics. Ecological Applications 21(3): 897–914.

Leal JF, Santos EBH, Esteves VI 2019. Oxytetracycline in intensive aquaculture: water quality during and after its administration, environmental fate, toxicity and bacterial resistance. Reviews in Aquaculture 11(4): 1176–1194.

Lengyel NL, Collie JS, Valentine PC 2009. The invasive colonial ascidian *Didemnum vexillum* on Georges Bank: ecological effects and genetic identification. Aquatic Invasions 4: 143-152.

Lunestad BT, Samuelsen O 2008. Veterinary drug use in aquaculture. In: Improving farmed Fish Quality and Safety (pp. 97-127). Woodhead Publishing.

Madsen T, Boyd HB, Nylén D, Pedersen AR, Petersen GI 2000. Environmental assessment of Virkon® Aquatic. Environmental Project No. 583. Copenhagen: Danish Environmental Protection Agency.

Mahon AR, Horton DJ, Learman DR, Nathan LR, Jerde CL 2018. Investigating diversity of pathogenic microbes in commercial bait trade water. PeerJ 6: e5468.

Mardones FO, Perez AM, Carpenter TE 2009. Epidemiologic investigation of the re-emergence of infectious salmon anemia virus in Chile. Diseases of Aquatic Organisms 84: 105-114.

Mardones FO, Perez AM, Valdes-Donoso P, Carpenter TB 2011. Farm-level reproduction number during an epidemic of infectious salmon anaemia virus in Southern Chile in 2007 – 2009. Preventive Veterinary Medicine 84: 213-227.

Martinsen B, Horsberg TE, Varma KJ, Sams R 1993. Single dose pharmacokinetic study of florfenicol in Atlantic salmon (*Salmo salar*) in seawater at 11°C. Aquaculture 112(1): 1–11.

MBP 2025. Marine Biosecurity Portal: Marine Pest Map. Accessed (16 July 2025), available online at https://marinebiosecurity.org.nz.

McEachran MC, Mladonicky J, Picasso-Risso C, Drake DAR, Phelps NBD 2023. Release of live baitfish by recreational anglers drives fish pathogen introduction risk. Preventive Veterinary Medicine 217: 105960.

McFadden A, Rawdon T, Gould B 2007. Response to a marine incursion of *Styela clava*. Surveillance 34(1): 4-8.

MFE 2019. New Zealand's Environmental Reporting Series: Our marine environment 2019. Publication number: ME 1468, Ministry for the Environment and Stats NZ, October 2019. 60p.

MNZ 2023. Guidance on Ballast Water Management. Maritime New Zealand, October 2023. 45p.

Morrisey D 2019. Ngāi Tahu Seafood Resources Ltd: Offshore farm assessment of environmental effects - biosecurity. Prepared for Ngāi Tahu Seafood Resources Ltd. Cawthron Report No. 3293. 28p.

Morrisey D, Plew D, Seaward K 2011. Aquaculture Readiness Data Phase II. MAF Technical Paper No: 2011/68. MAF, Wellington, New Zealand.

MPI 2016. Aquaculture Biosecurity Handbook: Assisting New Zealand's commercial and non-commercial aquaculture to minimise on-farm biosecurity risk. Ministry for Primary Industries, Wellington, New Zealand. 27 p. Available at: http://www.mpi.govt.nz/document-vault/13293.

MPI 2023. Bonamia ostreae Controlled Area Notice BRC 2023-2. Available at: https://www.mpi.govt.nz/dmsdocument/59776-Controlled-Area-Notice-Bonamia-ostreae-B2023-2-2023/ (accessed 17 July 2025).

MPI 2024. New Zealand Marine Pest ID Guide. Biosecurity New Zealand, Wellington. 34p.

Murray AG 2006. Hydrodynamics and epidemiology in the design of disease control policy for aquaculture. Proceedings of the 11th Symposium on Veterinary Epidemiology and Economics.

Murray AG, Hall M, Peeler EJ 2011. Wild-farmed interactions and disease emergence: An overview. Aquaculture 315(3–4): 39–46.

Ng C, Le TH, Goh SG, Liang L, Kim Y, et al. 2015. A comparison of microbial water quality and diversity for ballast and tropical harbor waters. PLOS ONE 10(11): e0143123.

Nowak BF 2007. Parasitic diseases in marine cage culture – An example of experimental evolution of parasites? International Journal for Parasitology 37(6): 581–588.

NTS 2025. Ngai Tahu Seafood Biosecurity Management Plan: Hananui Aquaculture Project. September 2025 (draft).

Padilla DK, McCann MJ, Shumway SE 2011. Marine invaders and bivalve aquaculture: sources, impacts and consequences. In: Shumway SE ed. Shellfish Aquaculture and the Environment, Wiley-Blackwell. Pp. 395-425.

Page MJ, Morrisey DJ, Handley SJ, Middleton C 2011. Biology, ecology and trials of potential methods for control of the introduced ascidian *Eudistoma elongatum* (Herdman, 1886) in Northland, New Zealand. Aquatic Invasions 6(4): 515-517.

Pedersen LF, Pedersen PB, Nielsen JL, Nielsen PH 2009. Peracetic acid degradation and effects on nitrification in recirculating aquaculture systems. Aquaculture 296(3–4): 246–254.

Piola RF, Johnston EL 2008. Pollution decreases native diversity and increases invader dominance. Diversity & Distributions 14: 329-342.

Pouliquen H, Le Bris H, Pinault L 1992. Experimental study of the therapeutic application of oxytetracycline, its attenuation in sediment and sea water, and implications for farm culture of benthic organisms. Marine Ecology Progress Series 89(1): 93–98.

Pye-MacSwain JK 1993. Pharmacokinetics and bioavailability of oxytetracycline in Atlantic salmon held in seawater at different temperatures. Notes 32(02): 0547.

Ramsay A, Davidson J, Landry T, Arsenault G 2008. Process of invasiveness among exotic tunicates in Prince Edward Island, Canada. Biological Invasions 10(8): 1311-1316.

Ruiz GM, Freestone AL, Fofonoff PW, Simkanin C 2009. Habitat distribution and heterogeneity in marine invasion dynamics: the importance of hard substrate and artificial structure. In: Rilov G, Crooks JA ed. Biological Invasions in Marine Ecosystems: Ecological, Management, and Geographic Perspectives. Berlin Heidelberg, Springer-Verlag. Pp. 321-332.

Ruiz GM, Rawlings TK, Dobbs FC, Drake LA, Mullady T, Huq A, Colwell RR 2000. Global spread of microorganisms by ships. Nature 408(6808): 49–50.

Salama NK, Murray AG 2011. Farm size as a factor in hydrodynamic transmission of pathogens in aquaculture fish production. Aquaculture Environment Interactions 2: 61-74.

Samuelsen OB 1989. Degradation of oxytetracycline in seawater at two different temperatures and light intensities, and the persistence of oxytetracycline in the sediment from a fish farm. Aquaculture 83(1-2): 7-16.

San Martin B, Fresno M, Cornejo J, Godoy M, Ibarra R, Vidal R, Lapierre L 2019. Optimization of florfenicol dose against *Piscirickettsia salmonis* in *Salmo salar* through PK/PD studies. PLoS One 14(5): e0215174.

Sant N, Delgado O, Rodriguez-Prieto C, Ballesteros E 1996. The spreading of the introduced seaweed *Caulerpa taxifolia* (Vahl) C. Agardh in the Mediterranean Sea: testing the boat transportation hypothesis. Botanica Marina 39: 427-430.

Santoro D 2024. Technical advice on the likelihood, speed, and impact of Bonamia ostreae spread from Big Glory Bay to Foveaux Strait. Biosecurity New Zealand Technical Paper No. 2024/05, prepared for the Bonamia Pest Management Programme, Ministry for Primary Industries, Wellington. 14p.

Schaffelke B, Deane D 2005. Desiccation tolerance of the introduced marine green alga Codium fragile ssp. tomentosoides – clues for likely transport vectors? Biological Invasions 7(4): 577-587.

Scott MJ, Jones MN 2000. The biodegradation of surfactants in the environment. Biochimica et Biophysica Acta (BBA) – Biomembranes 1508(1–2): 235–251.

Sinner J, Forrest BM, O'Brien M, Piola RF, Roberts B 2009. Fiordland marine biosecurity risk management: operational plan recommendations 2009-2013. Prepared for MAF Biosecurity New Zealand and Fiordland Marine Guardians. Cawthron Report No. 1621. 32p plus appendices.

Sinner J, Forrest BM, Taylor MD 2000. A strategy for managing the Asian kelp *Undaria*: final report. Cawthron Report No. 578. 122p.

South PM, Floerl O, Forrest BM, Thomsen MS 2017. A review of three decades of research on the invasive kelp *Undaria pinnatifida* in Australasia: An assessment of its success, impacts and status as one of the world's worst invaders. Marine Environmental Research 131: 243-257.

SRC 2017. Fiordland Marine Regional Pathway Management Plan. Southland Regional Council, New Zealand. 15p. Available at: https://www.es.govt.nz/about-us/plans-and-strategies/regional-plans/fiordland-marine-pathway-plan.

SRPMP 2019. Southland Regional Pest Management Plan 2019-2029. Publication No 2019-03, Environment Southland. 114p.

Straus DL, Meinelt T 2009. Acute toxicity of peracetic acid (PAA) formulations to *Ichthyophthirius multifiliis* theronts. Parasitology Research 104: 1237–1241.

Sun Y, Dai Z, Xiong W, Luo X, Zou M 2012. Fate of florfenicol in a simulated aquatic ecosystem and effects on sediment microflora. Water Environment Research 84(11): 2054-2059.

Tait LW, Lohrer AM, Townsend M, Atalah J, Floerl O, Inglis GJ 2020. Invasive ecosystem engineers threaten benthic nitrogen cycling by altering native infaunal and biofouling communities. Scientific Reports 10(1): 1581.

Valentine PC, Collie JS, Reid RN, Asch RG, Guida VG, Blackwood DS 2007. The occurrence of the colonial ascidian *Didemnum* sp. on Georges Bank gravel habitat: ecological observations and potential effects on groundfish and scallop fisheries. Journal of Experimental Marine Biology and Ecology 342(1): 179-181.

APPENDIX 1. PATHOGEN RISK ASSESSMENT

Prepared by Dr Colin Johnston to support the Hananui marine biosecurity AEE report

Pathogen risk assessment for the Hananui proposal

Introduction

As highlighted in the main report, this pathogen risk assessment seeks to provide, through a robust process of evidence consideration, an assessment of the new or increased risks to the environment from the proposal, and where unacceptable to develop risk mitigation measures that reduce the incremental risk to acceptable levels.

During the process of assessment and prioritization of risks, where useful considerations for the farming company to think about in relation to the productivity of their own stock are identified (but which do not materially alter the incremental risk to the environment) these will be highlighted as 'Key Feedback', rather than 'Risk Mitigation Recommendations'.

In recognition of the importance of the Bluff oyster fishery adjacent the proposed farming area, the risk assessment process includes specific consideration of flat oysters (*Ostrea chilensis*) in addition to Chinook salmon (*Oncorhynchus tshawytscha*).

Risk assessment process

Risk assessment consists of a number of recognised steps:

- Hazard identification – a process used to identify potential hazards and refine those to a list of hazards requiring a full risk assessment;
- Risk assessment – where each hazard identified is analysed to determine if risk mitigation is required;
- Risk mitigation – the development of risk mitigation recommendations, which may be included in translocation requirements, biosecurity risk management plan or veterinary health management plan; and
- Risk communication – the process of outlining and communicating how the risks were identified, the findings and recommendations. This report serves the purpose of risk communication in this circumstance.

The risk assessment process requirements the assignment of likelihoods and the estimation of risk during each stage of the assessment—release, exposure, consequence, and overall risk estimation. We must also define the thresholds used to determine when risk mitigation is required.

1. Likelihood Scale

The following table defines the qualitative likelihoods used throughout the risk assessment. Each term corresponds to an annual probability range, which allows consistent decision-making across release, exposure, and consequence assessments. If a hazard is rated negligible in any one of the three assessments (release, exposure, or consequence), the assessment for that hazard ends there.

Likelihood	Definition	Annual Probability
High (H)	The event would be very likely to occur	$0.7 < P \leq 1$
Moderate (M)	The event would occur with an even probability	$0.3 < P \leq 0.7$
Low (L)	The event would be unlikely to occur	$0.05 < P \leq 0.3$
Very Low (VL)	The event would be very unlikely to occur	$0.001 < P \leq 0.05$
Extremely low (EL)	The event would be extremely unlikely to occur	$0.000001 < P \leq 0.001$
Negligible (N)	The event would almost certainly not occur	$0 < P \leq 0.000001$

2. Release Assessment

The release assessment estimates the likelihood of a hazard entering the environment under consideration. The release pathway may be direct via faeces, urine, blood, mucus or other biological material shed by the farmed salmon into the water, or it may be indirect through the accumulation of infective stages by filter feeding molluscs or biofouling organisms and/or completion of the lifecycle of disease agents that cycle between fish and molluscs

3. Exposure Assessment

This step evaluates how likely it is that wild aquatic species near the proposed development site will be exposed to disease hazards originating from either infected sea pen reared Chinook salmon or infected oysters.

The goal is to determine the probability of disease establishment in native populations.

Key Factors Affecting Exposure

The likelihood of exposure depends on four critical factors:
- The ability of the disease agent to survive in the environment in a viable, infective form.
- The availability of susceptible hosts (e.g. wild fish or molluscs).
- The ease of infection in these hosts.
- The potential for onward transmission within wild populations once infection occurs.

Critical Exposure Pathways

1. *Route of Infection (Oral / Contact):*

Viable infective stages must either be:
- Ingested by a susceptible host, or
- Come into direct contact with susceptible fish or invertebrates.

Infection can occur via:
- The digestive tract,
- The skin and gills, or
- Filter feeding, in the case of oysters.

2. *Infective Dose:*

A sufficient concentration of infective stages must be present to initiate infection through ingestion or contact.

This evaluation relies on:
- Peer-reviewed scientific literature,
- Unpublished technical data, and
- The professional judgment and experience of the author.

4. Combined Likelihoods

When both release and exposure are not negligible, we combine their likelihoods to determine the overall probability of establishment. This is done using the matrix below. If the result from this matrix is negligible, the risk is effectively zero and we don't progress the hazard further.

Likelihood of exposure

Likelihood of release	High	Moderate	Low	Very Low	Extremely low	Negligible
High	High	Moderate	Low	Very Low	Extremely low	Negligible
Moderate	Moderate	Low	Low	Very Low	Extremely low	Negligible
Low	Low	Low	Very Low	Very Low	Extremely low	Negligible
Very Low	Very Low	Very Low	Very Low	Extremely low	Extremely low	Negligible
Extremely low	Extremely low	Extremely low	Extremely low	Extremely low	Negligible	Negligible
Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible

3. Consequence Definitions

The following table defines the impact levels associated with disease establishment. Only a scenario of widespread establishment is used for consequence assessment. We

discount self-limiting introductions i.e. short-term or one-off cases are not considered establishment.
A negligible consequence score ends the hazard's risk assessment.

Consequence	Definition
Extreme	Establishment of disease would cause substantial biological and economic harm at a regional or national level, and/or cause serious and irreversible environmental harm.
High	Establishment of disease would have serious biological consequences (high mortality or morbidity or loss of marketability) and would not be amenable to control or eradication. Such diseases would significantly harm economic performance at a regional level and/or cause serious environmental harm which is most likely irreversible.
Moderate	Establishment of disease would cause significant biological consequences (significant mortality or morbidity or loss of marketability) and may not be amenable to control or eradication. Such diseases could harm economic performance at a regional level on an ongoing basis and/or may cause significant environmental effects, which may or may not be irreversible.
Low	Establishment of disease would have moderate biological consequences and would normally be amenable to control or eradication. Such diseases may harm economic performance at a local level for some period and/or may cause some environmental effects, which would not be serious or irreversible.
Very Low	Establishment of disease would have mild biological consequences and would be amenable to control or eradication. Such diseases may harm economic performance at a local level for a short period and/or may cause some minor environmental effects, which would not be serious or irreversible.
Negligible	Establishment of disease would have no significant biological consequences and would require no management. The disease would not affect economic performance at any level and would not cause any detectable environmental effects.

4. Risk Estimation – Combining Likelihood and Consequence

Once we have:
- A combined likelihood score (from release and exposure), plus
- A consequence score (from disease establishment),

we use the matrix below to determine overall risk level.

Combined likelihood of release and exposure	Negligible	Very Low	Low	Moderate	High	Extreme
High	Negligible risk	Very low risk	Low risk	Moderate risk	High risk	Extreme risk
Moderate	Negligible risk	Very low risk	Low risk	Moderate risk	High risk	Extreme risk
Low	Negligible risk	Negligible risk	Very low risk	Low risk	Moderate risk	High risk
Very low	Negligible risk	Negligible risk	Negligible risk	Very low risk	Low risk	Moderate risk
Ext. Low	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk	Low risk
Negligible	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk

Consequences of establishment and spread

Key Rule: Acceptable Level of Protection (ALOP)
We define acceptable risk as very low or below. If the outcome is moderate or above, mitigation is required.

5. Risk Mitigation & Threshold for Action

If a hazard's risk exceeds very low, we:
- Flag the hazard for mitigation,
- Consider scale of salmon production and proximity to sensitive areas like the Bluff oyster fishery.

We then present risk mitigation options to reduce the overall risk to very low or below based on biology of the hazard and/or known tools used overseas or elsewhere in New Zealand.

Potential hazard organisms – New Zealand waters

Host: Chinook salmon (*Oncorhynchus tshawytscha*)

Agent	Comment	Report(s)
VIRUSES		
Aquatic birnavirus	Found in non-clinical returning wild salmonids	Tisdall & Phipps (1987)
BACTERIA		
Piscirickettsia spp.	NZ-RLO1, 2 & 3	Brosnahan *et al.* (2017a), Brosnahan *et al.* (2019b)
Yersinia ruckeri O1b		Anderson *et al.* (1994)
Tenacibaculum spp.	Identified as marine flexibacter by Boustead (1989)	Brosnahan *et al.* (2019a)
Nocardia sp.		Boustead (1989), Brosnahan *et al.* (2017b)
Vibrio spp.		Boustead (1989), Wards *et al.* (1991), Anderson (1996)
Flavobacterium sp. (freshwater)		Anderson (1996)
Flavobacterium psychrophilum		Boustead (1989)
Bacterial gill disease	General syndromic term	Boustead (1989)
Pasteurella sp.		Boustead (1989)
Streptococcus sp.		Anderson (1996)
PARASITES		
Myxobolus cerebralis	"Whirling disease" - myxosporean	Hewitt & Little (1972), Boustead (1989), Boustead (1993)
Cochliopodia sp.	Neoparamoeba-like organism	Tubbs *et al.* (2010)
Chilodonella sp.	Protozoan	Boustead (1989)
Icthyophthirius multifiliis	"White spot" disease	Boustead (1989)
Paramoeba sp. & *Neoparamoeba perurans*	Amoebic gill disease	Anderson (1996), Diggles *et al.* (2002)
Hepatoxylon trichiuri	Tapeworm larvae – salmon function as intermediate host (presumptive identification)	Boustead (1989)
Derogenes varicus	Gastrointestinal tract	Hine, Jones & Diggles (2000)
Lecithocladium seriolellae	Gastrointestinal tract	Hine, Jones & Diggles (2000)
Parahemiurus sp.	Gastrointestinal tract	Hine, Jones & Diggles (2000)

Tubulovesicula angusticauda	Gastrointestinal tract	Hine, Jones & Diggles (2000)
Phyllobothrium sp.	Tetraphyllidean metacestode in gastrointestinal tract	Hine, Jones & Diggles (2000)
Heduris spinigera	Nematode isolated from stomach of a single fish	Hewitt & Hine (1972)
Hysterothylacium sp.	Nematode from gastrointestinal tract	Hine, Jones & Diggles (2000)
Eustrongylides sp.	Nematode from *O. nerka*	Hine, Jones & Diggles (2000)
Paenodes nemaformis	Parasitic copepod of gills & fins, reported once from salmon in 1962	Boustead (1989)
Caligus longicaudatus	Skin copepod parasite from *O. nerka*	Hine, Jones & Diggles (2000)
Cirolana sp. and *Nerocila orbignyi*	Isopod crustacean likely synonymous with *Nerocila* sp.	Scott (1964), Boustead (1989)

Host: Flat oyster (*Ostrea chilensis*)

Agent	Comment	Report(s)
VIRUSES		
Herpes-like virus		Hine, Wesney & Besant (1998)
BACTERIA		
Intracellular bacteria	Rickettsia-like inclusions	Fryer & Lannan (1994)
Vibrio spp.		Diggles *et al.* (2002)
PARASITES		
Bonamia ostreae		Lane, Webb & Duncan (2016)
Bonamia exitiosa		Hine, Cochennec-Laureau & Berthe (2001), Cranfield *et al.* (2005)
Apicomplexan X	Known as APX	Hine (2002a)
Klossia-like coccidian		Hine & Jones (1994)
Bucephalus longicornutus		Howell (1967), Lane (2018)
Microsporidium rapuae		Jones (1981), Hine & Jones (1994)
Pseudomyicola-like copepods		Hine (1997)
Polydora sp., *Boccardia* sp.	Mudworms	Ranier (1973), Read (2010)

Preliminary assessment of potential hazards

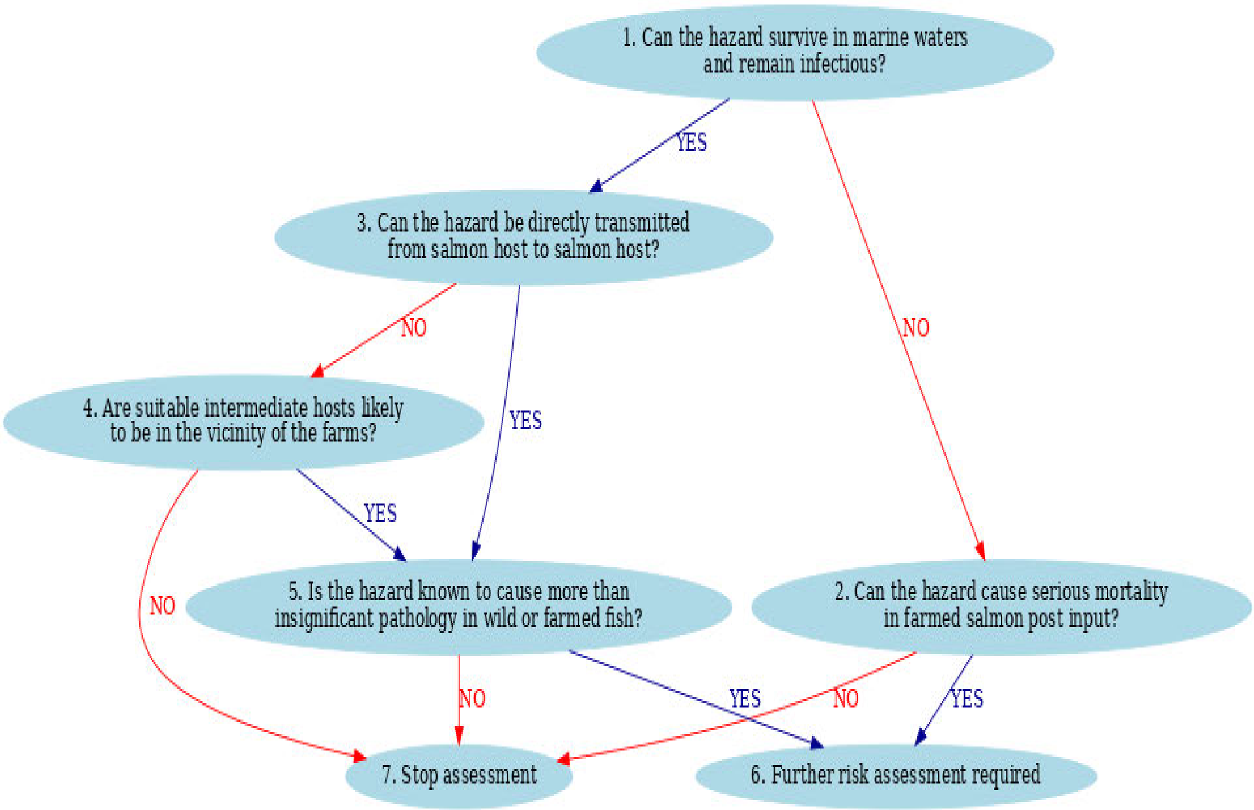
Salmon potential hazards

Salmon potential hazards were assessed against a series of criteria to determine if further assessment as a hazard was necessary.

In summary, a potential hazard is considered a hazard requiring detailed assessment if:

- It does not transmit in marine waters but can cause significant mortality or disease in transferred stock at sea; OR
- Can transmit directly between salmon hosts in the water column, and causes more than insignificant disease or pathology in wild or farmed fish; OR
- It transmits via intermediate hosts, which are likely to be present around the farm(s), and causes more than insignificant disease or pathology in wild or farmed fish.

This may be visually represented in the decision flowchart below:



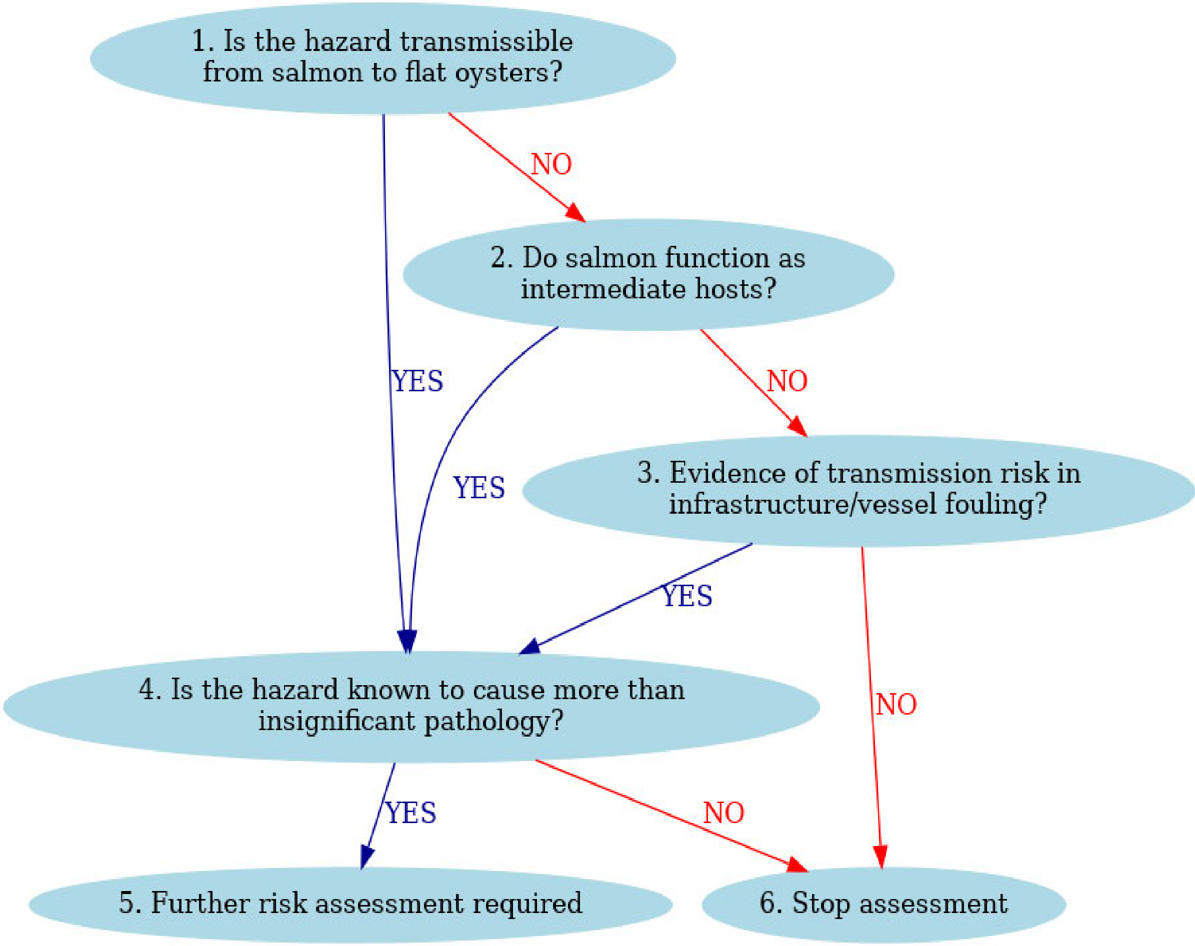
Flat oyster potential hazards

Flat oyster potential hazards were assessed against a series of criteria to determine if further assessment as a hazard was necessary.

In summary, a potential hazard is considered a hazard requiring detailed assessment if:

- It is transmissible from salmon to flat oysters; OR
- If salmon may act as an intermediate host for a flat oyster hazard, and it causes more than insignificant disease or pathology in flat oysters; OR
- There is transmission risk utilising fouling organisms which are likely to be present around the farm(s), and it causes more than insignificant disease or pathology in flat oysters.

This may be visually represented in the decision flowchart below:



Hazard	1. Survival in marine waters if released?	2. Potential for serious mortality post input (i.e. transfer-associated episodes)	3. Direct transmission between salmon?	4. If indirect transmission, are intermediate hosts in vicinity?	5. Does the hazard cause more than incidental pathology or disease?	Does the pathogen require further consideration?
Aquatic birnavirus	Yes	N/A	Yes	N/A	Yes	**YES**
Piscirickettsia spp.	Yes	N/A	Yes	N/A	Yes	**YES**
Yersinia ruckeri	No	Yes	N/A	N/A	N/A	**YES**
Tenacibaculum spp.	Yes	N/A	Yes	N/A	Yes	**YES**
Nocardia sp.	Yes	N/A	Ye	N/A	Yes	**YES**
Vibrio sp.	Yes	N/A	Yes	N/A	Yes	**YES**
Flavobacterium sp.	No	No	N/A	N/A	N/A	**NO**
Flavobacterium psychrophilum	No	No	N/A	N/A	N/A	**NO**
Bacterial gill disease	No	No	N/A	N/A	N/A	**NO**
Pasteurella sp.	Yes	N/A	Yes	N/A	Yes	**YES**
Streptococcus sp.	Yes	N/A	Yes	N/A	Yes	**YES**
Myxobolus cerebralis.	No	No	N/A	N/A	N/A	**NO**
Cochliopodia sp.	No	No	N/A	N/A	N/A	**NO**
Chilodonella sp.	No	No	N/A	N/A	N/A	**NO**
Icthyophthirius multifiliis	No	No	N/A	N/A	N/A	**NO**
Paramoeba.sp **& Neoparamoeba perurans**	Yes	N/A	Yes	N/A	Yes	**YES**
Hepatoxylon trichiuri	Yes	N/A	No	Yes	No	**NO**[a]

Appendix 1: Pathogen risk assessment

Derogenes varicus	Yes	N/A	No	Yes	No	**NO[a]**
Lecithocladium seriolellae	Yes	N/A	No	Yes	No	**NO[a]**
Parahemiurus sp.	Yes	N/A	No	Yes	No	**NO[a]**
Tubulovesicula angusticauda.	Yes	N/A	N/A	Yes	No	**NO[a]**
Phyllobothrium sp.	Yes	N/A	No	Yes	No	**NO[b]**
Heduris spinigera.	Yes	N/A	No	Yes	No	**NO[c]**
Hysterothylacium sp.	Yes	N/A	N/A	Yes	No	**NO[c]**
Eustrongylides sp.	No	No	N/A	N/A	N/A	**NO**
Paeonodes nemaformis	No[d]	No	N/A	N/A	N/A	**NO**
Caligus longicaudatus	Yes	N/A	Yes	N/A	N/A	**YES**
Cirolana sp.* and *Nerocila orbignyi	Yes	N/A	Yes	N/A	N/A	**YES**
Hazard	**Transmissible from salmon to flat oysters**	**Can salmon function as intermediate hosts?**	**Does biofouling associated with farm and operations represent a transmission risk?**	**Does hazard cause more than incidental pathology or disease?**		**Does the hazard require further consideration?**
Herpes-like viruses	No	No	Yes	No[e]		**NO**
Intracellular bacteria	No	No	Yes	No[f]		**NO**
Vibrio spp.	Possible	N/A	Yes	Possible		**YES**
Bonamia exitiosa	No	No	Yes	Yes		**YES**

Bonamia ostreae	No	No	Yes	Yes		**YES**
Apicomplexan X	No	No	Yes	Possible		**YES**
***Klossia*-like coccidian**	No	No	Possible	No[g]		**NO**
Bucephalus longicornutus	No	No	No	Yes		**YES**
Microsporidium rapuae	No	No	Possible	No[h]		**NO**
***Pseudomyicola*-like copepods**	No	No	Possible	No		**NO**
Polydora sp., Boccardia sp.	No	No	Possible	Yes		**YES**

Table 1: Matrix of consideration of hazard characteristics against potential hazards list

Footnote(s):

a) *H. trichiuri, D. varicus, L. seriolellae, Parahemiurus* sp., and *T. angusticauda* all require intermediate hosts. In the case of *H. trichiuri* (tapeworm) salmon are the intermediate hosts where plerocercoid larvae encyst. The life cycle requires sharks to complete so building epidemic infestation and adverse consequences are unlikely. *D. varicus* trematode reported from the gut of salmon releases eggs in faeces which must hatch into miracidia which enter first intermediate host (marine gastropods) where they develop and are released as ceraria to infect planktonic copedpods; small fish are infected by consuming the copepods and develop metacercaria. Theses small fish then need to be consumed by the final host. Such a complex life cycle minimizes likelihood of epidemic infestation. *L. seriolellae, Parahemiurus* sp. and *T. angusticauda* (treamtodes) all share a similar three-host lifecycle Salmon being definitive host iin gastrointestinal tract, with marine gastropods and small fish the intermediate hosts. Reports of detection are sparse and the complex life cycle limits risk of epidemic infestation.

b) *Phyllobothrium* sp. is infrequently reported, and not in association with more than incidental pathology. Its lifecycle relies on intermediate hosts making epidemic infestation unlikely.

c) *H. spinigera* and *Hysterothylacium;* both these nematodes have amphipod (or crustacean) intermediate hosts. Again, the multiple host lifecycles make epidemic infestations unlikely, and reports are few despite decades of aquaculture of salmonids.

d) *Paenodes nemaformis*, a parasitic copepod of the Ergasilidae family is found in freshwater. It would not therefore represent a risk in the marine environment.

e) The 1998 report of replication of a herpes-like virus in the veligers of *O. chilensis* was experimental through cohabitation experiments from OsHV-1 infected Pacific oysters. So, whilst flat oysters may permit replication, this is of greater importance in the epidemiology of ostreid herpesvirus outbreaks in Pacific oysters.

f) Intracellular bacteria (rickettsia-like and chlamydia-like bacteria) have been associated with disease in scallops when present at high intensities in the gills (Hines & Diggles, 2002), although they are also reported from the digestive gland of otherwise healthy shellfish across the globe and are characterized as frequently benign (Fryer & Lannan, 1994). There are at least eight genus level lineages of Rickettsiaceae and 2 main clades just within the Rickettsia genus. Rickettsiaceae and rickettsia-like organisms have been reported from 98% of scallops in the Marlborough Sounds and 81% from Coromandel waters in a survey in the year 2000. Organisms from both the North Island and South Island were further characterised in 2002. These organisms are ubiquitous in New Zealand bivalves, present microscopically differently to the rickettsia of salmonids and are unequivocally different organisms to the finfish rickettsiae.

g) *Klossia*-like coccidian was identified in <1% of flat oysters in the Foveaux Strait as an incidental finding.

h) *Microsporidium rapuae* was reported from Leydig tissue near the gut of flat oysters (Jones, 1981) however according to Hine & Jones (1994) they appear not to harm their hosts.

Refinement of hazard lists (further consideration)

Following an initial review of the potential hazard list against those criteria indicated above, the following potential hazards have been taken forward for further refinement to produce the definitive hazard list.

Chinook salmon specific

Aquatic birnavirus

Birnaviruses are non-enveloped double stranded RNA viruses of the genus *Aquabirnavirus* in the Family Birnaviridae. An aquatic birnavirus (IPNV Genogroup 5) has been reported from returning wild run Chinook salmon in the South Island which did not display and clinical signs. A similar virus was also reported from turbot mortalities in the North Island (Tisdall & Phipps 1987, Davies *et al.* 2010).

Whilst the isolated aquatic birnavirus appeared non-clinical in the returning sea run salmon, the identification from diseased turbot (albeit primarily investigated due to apparent bacterial disease (Diggles *et al.* 2000)) leaves open the possibility that aquatic birnaviruses may be pathogenic to non-salmonid wild fish in the vicinity of farms.

Aquatic birnaviruses will therefore be retained for detailed risk assessment.

***Piscirickettsia* spp.**

Piscirickettsia species are gram negative, obligate intracellular gamma proteobacteria within the Family Piscirickettsiaceae.

There are at least three strains of *Piscirickettsia* identified from the waters around the South Island of New Zealand. Two strains have been associated with clinical disease and elevated mortality in Chinook salmon in the Marlborough Sounds (Brosnahan *et al.* 2017a, Gias *et al.* 2018).

Given the epidemic potential of the closely related *P. salmonis* strains isolated in Chile (Cvitanich *et al.* 1991), *Piscirickettsia* spp. will be retained for detailed risk assessment.

Yersinia ruckeri

Yersinia ruckeri is a member of the Enterobacteriaceae Family with a global cosmopolitan distribution (Carson & Wilson 2009). The strain present in New Zealand is the O1b serotype, biotype 1 (Barnes *et al.* 2016). The more virulent Hagerman strain (O1a) is exotic to New Zealand.

As *Y. ruckeri* is a freshwater bacterium, it has greatly reduced survival in seawater (Thorsen *et al.* 1992), and its adhesion to fish is inhibited (Altinok 2004) there is negligible risk of transmission and establishment in the marine environment and it does not therefore represent an incremental environmental risk in the Foveaux Strait and will not be subject to detailed risk assessment.

It may under certain circumstances, where smolts have been exposed prior to transfer to seawater and subsequently become stressed, result in epidemic mortality events in sea water (Sparboe *et al.* 1986).

Because of this post-input potential **Key Feedback** for the proponent is:

- ***Monitor freshwater hatcheries for* Yersinia ruckeri;**
- ***Ensure good water quality pre-transfer;***
- ***Consider the use of Yersinia vaccines if outbreaks occur in the hatchery or at sea post-input***

***Tenacibaculum* spp.**

Tenacibaculum spp. includes *T. maritimum*, *T. dicentrarchi* and *T. solae*. Whilst *T. maritimum* is perhaps the most well known species we may consider Tenacibaculosis as a common presenting syndrome with similar behaviours of the bacteria involved.

Typically Tenacibaculosis is characterized by skin ulcers, mouth, gill, and fin erosions most often in fish exposed to environmental stressors (Mitchell & Rodger 2011). *Tenacibaculum* spp. are ubiquitous in the New Zealand marine environment and have been recorded from blue cod and kingfish (Tubbs *et al.* 2006). Transmission is horizontal via seawater, although Ferguson *et al.* (2010) also reported the potential for jellyfish to act as a route of transmission.

As *Tenacibaculum* spp. are ubiquitous in New Zealand waters, and generally only result in disease in stressed fish at higher densities, they are unlikely to result in increased risk to wild fish populations in the Foveaux Strait and thus do not require a detailed risk assessment. However, because of risk of impact to farmed stock and to reduce risk of spill over of pathogen into the wild in large amounts we will consider mitigation of these ubiquitous agents in a widely applicable **Best Practice Biosecurity & Health Management** section of the AEE report.

***Nocardia* sp.**

Nocardia spp. are weakly gram-positive, partially acid-fast, filamentous rod-shaped bacteria (Buller 2014). This genus of bacteria is globally ubiquitous in soil, freshwater and marine environments but causes only limited disease in highly stressed fish. The likelihood that they would cause a risk to the environment incrementally greater than that which currently exists is negligible and therefore they will not be subject to a detailed risk assessment.

***Vibrio* sp.**

Vibrio spp. bacteria are ubiquitous in marine environments (Austin & Austin 2007), with most species being facultatively pathogenic to stressed fish (Diggles *et al.* 2002). Whilst the species of vibrio that can cause disease in fish tend to be different to those that have an impact bivalve shellfish there are some e.g. *Vibrio anguillarum* which could affect both species (Shafiee *et al.* 2024).

As *Vibrio* spp. are ubiquitous in New Zealand waters, and generally only result in disease in stressed fish at higher densities, they are unlikely to result in increased risk to wild fish populations in the Foveaux Strait and thus do not require a detailed risk assessment. However, because of risk of impact to farmed stock and to reduce risk of spill over of pathogen into the wild in large amounts we will consider mitigation of these ubiquitous agents in a widely applicable **Best Practice Biosecurity & Health Management** section of the AEE report.

***Pasteurella* sp. and *Streptococcus* sp.**

The reports of both the *Stretococcus* sp. bacterium (Anderson 1996) and the *Pasteurella* sp. bacterium (Boustead 1989) appear to be individual, incidental isolations and in the decades since then there have been no further reports published. As such, whilst they will not be subject to detailed risk assessment, the **Best Practice Biosecurity & Health Management** section of the AEE report will cover precautionary mitigation.

Paramoeba* sp. and *Neoparamoeba perurans

The primary causative agent of amoebic gill disease (AGD) is *Neoparamoeba perurans*. AGD is increasing in importance as a production impacting disease in salmon growing regions where it has not previously been an issue (Murray *et al.* 2016, Martinsen *et al.* 2018)

Chinook salmon have historically been considered to be resistant to AGD, despite the amoeba being detectable on their gills (Munday *et al.* 2001, Tubbs *et al.* 2010), however the author has diagnosed clinical AGD in environmentally challenged Chinook salmon in New Zealand, and the risk is expected to increase as climate change continues.

However, the risk to wild populations of fish is considered to be negligible. Global research on AGD has indicated that disease is only caused in cultured salmonids at higher densities (Mitchell & Rodger 2011) and wild fish, even in the vicinity of infected salmon sea pens do not seem to become clinically affected (Douglas-Helders *et al*. 2002). For these reasons this hazard does not require detailed risk assessment. Although management of AGD on the farms may become necessary in the future.

A **Key Feedback** for the proponent is to ensure that ***health check routines include surveillance for clinical AGD during summer months for early detection of issues.***

Caligus longicaudatus

Hine, Jones and Diggles (2000) reported 26 separate findings of a *Caligus* sp. in marine fish in the waters around New Zealand. They have a direct life cycle and are therefore capable of increasing the population prevalence in farmed fish, with potential for overspill into wild populations of fish.

Because they exist and can establish a self replicating population theoretically, it is reasonable to subject them to a detailed risk assessment.

Cirolana* sp. and *Nerocila orbignyi

Isopods have been reported from a number of marine fish species in New Zealand (Hine, Jones & Diggles 2000) and may cause some losses in farmed chinook salmon when fish consume the free-swimming isopods (Boustead 1989). In some cases, isopods also consume and replace the tongue of fish, acting as a functional replacement. Overall, however, the impact is restricted and for this reason these species will not require detailed risk assessment.

Flat oyster specific

***Vibrio* sp.**

Vibrio spp. bacteria are ubiquitous in marine environments (Austin & Austin 2007). Whilst it is possible that an overspill of vibrio bacteria from diseased salmonids could impact adjacent bivalves the species are few and **Best Practice Biosecurity & Health Management** on the farm should mitigate that possibility.

The presence of bivalves as fouling organisms on the farming infrastructure should not increase the titre of food risk vibrio bacteria either. *Vibrio parahaemolyticus* is a recognised food safety risk, but its titres only increase significantly in oysters exposed during tidal cycles, and Cole *et al.* (2015) demonstrated that oysters held subtidally in the water column (as for biofouling) have naturally reduced populations of these vibrio bacteria than benthically resident bivalves. In addition, as flat oysters would be submerged at all times the environmental pressure of intertidal exposure would not exist. Salmonids are not a source of *V. parahaemoyticus* replication either.

Considering these factors it is not necessary to subject this hazard to a detailed risk assessment.

Bonamia exitiosa and Bonamia ostreae

Bonamia spp. are haplosprodian parasites with a direct lifecycle of oyster to oyster spread via uninucleate microcells (Hine 1996). It may also be translocated in biofouling (Culloty & Mulcahy 2007).

The Foveaux Strait *O. chilensis* fishery is one under stress from a number of risk factors including *B. exitiosa* epidemics, and *B. ostreae* on the Strait's margin (in Big Glory Bay, Stewart Island). The fishery is recognised as one of the last flat oyster fisheries remaining. As such, whilst chinook salmon do not act as vectors or reservoirs of bonamiosis, the potential for fouling on vessels and infrastructure to add to the infection pressure means that *Bonamia* spp. will be subject to a detailed risk assessment.

Apicomplexan X (APX)

Apicomplexan X (APX) is reported already from *O. chilensis* in the Foveaux Strait at quite high prevalence (85% or more) (Hine and Jones 1994, Hine 2002a, Suong *et al.* 2017). Not only is it found in *O. chilensis*, but in a variety of other hosts in New Zealand waters, and all in apparently healthy animals (Suong *et al.* 2017).

Given its widespread presence already, its apparent lack of health issues unless in environmentally stressed animals, and the negligible host contribution of biofouling to the overall permissive host population size in the area, it is unlikely to represent anything other than a negligible incremental risk and this hazard does not require a detailed risk assessment.

Bucephalus longicornutus

Infection of the salmon with adult lifestages of *Bucephalus longicornutus* was identified as a potential risk in the hazard identification process. While *Oncorhynchus tshawytscha* has not been shown previously to be a definitive host for the adult life-stage, it was listed for further consideration. It must be noted, however, that there have been no reports of the presence of adult *B. longicornutus* in Chinook salmon in other farming areas in New Zealand despite active health surveillance and host/parasite research (Hewitt & Hine 1972, Hine, Jones & Diggles 2000) and surveys of bivalves in the Marlborough Sounds salmon farming areas has not detected the presence in gonads (Hine, 2002b). The parasite has been recorded in the Foveaux Strait (Howell 1967). The risk is already present in the area, and therefore any additional risk from the farm must be considered.

Literature indicates most likely intermediate hosts for *Bucephalus longicornutus* as:

- Monkfish (*Kathetostoma giganteum*), a bottom dwelling species found in Foveaux Strait, although the main target fishery is on the Stewart–Snares shelf west of Stewart Island (statistical areas 029–030).
- *Acanthoclinus littoreus*, found in shallow depths < 15m.
- *Scorpaena cardinalis*, found only in northern NZ and is a benthic dwelling species
- *Tripterygion* sp., a shallow-water subtidal reef fish (triple fin).

Throughout a number of surveys for this farm application only one triple fin (*Forsterygion maryannae*), was observed at the application location. In addition, a previous survey of local recreational fishing effort (Davey & Harthill 2011), a survey of the Foveaux Strait ecosystem and the effect of oyster dredging (Michael 2007), and a drift underwater video (DUV) survey to examine dredge impacts on demersal fishes and benthic habitat complexity in Foveaux Strait (Carbines & Cole 2009) have all failed to identify, in the Foveaux Strait, any of the most likely small fish host species for this oyster parasite.

The described life history of *Bucephalus longicornutus* indicates that the small fish species indicated above become infected via the skin, whereupon the parasite encysts in the tissues of the secondary intermediate host. These small fish may then be consumed by predatory fish, when the parasite excysts and becomes an adult in the intestine. For the Chinook salmon to become infected would involve the salmon predating on smaller fish species. Based on the above information the identified fish hosts are shallow and/or bottom dwelling species without swim bladders (Monkfish and Triple fin all lack swim bladders) and infected fish would have to swim up into the water column and would have to actively maintain themselves in the water column (due to the lack of a swim bladder) to be consumed by the salmon.

As the pens are likely to be 15m above the benthic habitat and in strong water currents it is considered highly unlikely for infected fish to be consumed by salmon. In addition, the use of camera-based feeding systems will ensure that the salmon are fed to satiation and thus are considered unlikely to consume prey fish.

On closer examination this hazard does not require any further detailed risk assessment.

However, a **Key Feedback** to the proponents would be to organise ***a survey of the gastrointestinal tract of a sample of salmon to be carried out within the first year of operation. This may be carried out at time of first harvest, with gastrointestinal tracts of 60 fish opened and examined for the adult life-stage of B. longicornutus.***

***Polydora* sp. and *Boccardia* sp. (mudworms)**

Spionid polychaetes, or mudworms, can burrow into bivalve shells and cause growth impacts and quality issues in the bivalve molluscs. The adult forms exist in burrows in the shells of bivalves, and their presence can be exacerbated by a build up of fine sediments in the area of the bivalves.

Given the expected current speeds, the depth of the water and the placement of farming structures over sandy bottom, with an apparent high energy environment, this risk is mitigated by two main factors:

1. The high energy environment which results in low levels of deposition below the farms; and
2. The benthic environment of sand with high sea bed shear stress being a hostile environment for bivalves to survive (The potential effects of salmon and finfish aquaculture on wild oysters (Ostrea chilensis) in Foveaux Strait; NIWA Client Report Number 2019085WN; Kamermans (2018)), thus virtually eliminating bivalve hosts for mudworms.

As a result of this it is considered that the farms do not pose more than negligible risk of exacerbating mudworm infestation and these hazards will not be subject to detailed risk assessment.

Hazards for detailed risk assessment

The following hazards have been identified for detailed risk assessment and potential risk management measures:

1. Aquatic birnaviruses
2. *Piscirickettsia* spp.
3. *Caligus* spp.
4. *Bonamia exitiosa* and *B. ostreae*

Infection with Aquatic Birnaviruses

Aetiological agent:

Aquatic birnaviruses are non-enveloped viruses with a double-stranded RNA genome residing within the genus *Aquabirnavirus* of the Family Birnaviridae.

Current status in New Zealand

An aquatic birnavirus (IPNV Genogroup 5) has been reported from returning wild run Chinook salmon in the South Island which did not display and clinical signs. A similar virus was also reported from turbot mortalities in the North Island (Tisdall & Phipps 1987, Davies *et al.* 2010).

Reason for risk assessment

Whilst the isolated aquatic birnavirus appeared non-clinical in the returning sea run salmon, the identification from diseased turbot (albeit primarily investigated due to apparent bacterial disease (Diggles *et al.* 2000)) leaves open the possibility that aquatic birnaviruses may be pathogenic to non-salmonid wild fish in the vicinity of farms.

Release assessment

Aquatic birnaviruses will only enter the environment of the farm, in levels in excess of that naturally and currently occurring, through either the introduction of smolts which have been produced from infected broodstock, or by the stock on the farm becoming infected with an aquatic birnavirus within the Foveaux Strait and that virus replicating in the population and being shed from those fish.

For release by the former route to occur, broodstock would have to be infected with an aquatic birnavirus either in the sea and returned to freshwater, or by exposure at a freshwater hatchery. Those broodstock would have to avoid detection during routine surveillance (e.g. the Australian salmon export surveillance scheme run through the MPI), pass the infection via ovarian fluid or milt while surviving egg surface disinfection processes, then survive within the juveniles until input to the sea farms.

A comprehensive survey of wild marine fish for aquabirnavirus has not been undertaken in New Zealand, though surveys of thousands of cultured and returning chinook salmon over many years have shown the virus to be rare (Anderson 1995, 1996, 1998, McIntyre *et al*. 2010).

Considering the apparent very low prevalence of the virus in the environment the likelihood of the broodstock becoming infected and the infection surviving and remaining undetected to smolt input is considered ***negligible***. The likelihood of salmon on the farm becoming infected with aquatic birnavirus from wild fish, spreading through the population and releasing the virus is considered to be **very low.**

Exposure assessment

If aquatic birnaviruses were released from the sea pens, they would remain viable in the environment for extended periods of time. Bovo *et al.* (2005) report minimal loss of infectivity over 10 weeks in filtered seawater at 4 and 10 Celsius. It would be expected that viability would be less in unfiltered raw seawater. In addition, the virus is not inactivated by high body temperatures of seabirds (Reno 1999).

Infection of wild fish relies upon a sufficient quantity of virus coming into contact with susceptible hosts passing the sea pens. Whilst aquatic birnaviruses are robust, they will be subject to dispersion. This reduces the titre per unit volume of water and reduces the likelihood of an infectious dose coming into contact with a susceptible wild host.

The infectious dose of birnaviruses by immersion challenge varies by species:

Species (life stage)	Immersion dose & exposure	Outcome / note	Reference
Atlantic salmon (Salmo salar) post-smolts	< 0.1 $TCID_{50} \cdot mL^{-1}$, 4 h at 10 °C	Estimated minimum infectious dose (IID) for bath immersion; study modeled dose–response and shedding	Mutoloki, S., Jarp, J., Evensen, Ø. (2006). Infectious dose and shedding of Infectious Pancreatic Necrosis Virus in Atlantic salmon post-smolts. Journal of Fish Diseases, 29(3), 177–186.
Rainbow trout (Oncorhynchus mykiss) fry	$1{\times}10^5$–$5{\times}10^5$ $TCID_{50} \cdot mL^{-1}$, 10–40 min to several hours	Robust infection/mortality in bath challenges; commonly used dose range in controlled trials	Wolf, K., Snieszko, S.F., Dunbar, C.E., Pyle, E. (1960). Virus nature of infectious pancreatic necrosis in trout. Proceedings of the Society for Experimental Biology and Medicine, 104(1), 105–108.
Brook trout (Salvelinus fontinalis)	$1{\times}10^5$ $PFU \cdot mL^{-1}$, 5 h immersion	Standardized immersion challenge that reliably established infection; protocol paper	McAllister, P.E., Owens, W.J. (1992). Infectious pancreatic necrosis virus in the environment: relationship to effluent from fish hatcheries. Journal of Aquatic Animal Health, 4(4), 298–303.

Arctic char (Salvelinus alpinus)	1×10^3 or 1×10^5 PFU·mL^{-1}, 5 h immersion; fry at 46–95 d post-hatch	Dose-dependent infection; study tracked mortality and carrier prevalence post-challenge	McAllister P, Beba, J & Wagner B. (2000). Susceptibility of Arctic Char to Experimental Challenge with Infectious Hematopoietic Necrosis Virus (IHNV) and Infectious Pancreatic Necrosis Virus (IPNV). Journal of Aquatic Animal Health. 12, 35-43
Rainbow trout (additional example)	3.5×10^5 PFU·mL^{-1} immersion	Used as the infective immersion dose to evaluate responses; confirms range above	Taksdal, T., *et al*. (1997). Protection of Atlantic salmon (Salmo salar L.) against infectious pancreatic necrosis (IPN) by vaccination with a poly I:C adjuvanted inactivated whole virus vaccine. Fish & Shellfish Immunology, 7(7), 473–484.

Atlantic salmon are exquisitely sensitive to the IPNV birnavirus, other species have higher minimum infectious doses.

Realistically dose of around 10^5 $TCID_{50}$ (or PFU)/mL would be expected to result in infection in wild fish. Given that chinook salmon are non-clinical carriers (Tisdall & Phipps 1987, Davies et al. 2010) we may expect virus titres in carrier fish to be lower than in clinically infected fish. This is indeed the case:

Infection Status & Species	Sample Type & Timing	Titre	Reference
Clinically infected – Atlantic salmon (Salmo salar) post-smolts	Pancreas, bath challenge at 10 °C; Day 6, Day 13 (peak), Day 29	Day 6: 3.4×10^3 $TCID_{50}$/g; Day 13 (high virulence): 2.2×10^8 $TCID_{50}$/g; Day 29: 8.5×10^5 $TCID_{50}$/g; low virulence peak: 6.4×10^7 $TCID_{50}$/g; Mortality up to 38%	Mutoloki, S., Jarp, J., & Evensen, Ø. (2006). Infectious dose and shedding of Infectious Pancreatic Necrosis Virus in Atlantic salmon post-smolts. Journal of Fish Diseases, 29(3), 177–186.

Non-clinical carriers – Brook trout (Salvelinus fontinalis)	Organs (pyloric caeca–pancreas, anterior kidney, posterior kidney, liver, intestine, gonad, spleen) at 8 vs 76 weeks post-infection (wpi)	Pyloric caeca–pancreas: 4.56 → 3.98 $\log_{10}$ $TCID_{50}$/g; Anterior kidney: 3.63 → 3.00; Posterior kidney: 3.52 → 3.38; Liver: 3.48 → 3.35; Intestine: 3.31 → 3.22; Gonad: 3.09 → 3.67; Spleen: 2.88 → 3.21	McAllister, P. E., & Owens, W. J. (1992). Infectious pancreatic necrosis virus in the environment: Relationship to effluent from fish hatcheries. Journal of Aquatic Animal Health, 4(4), 298–303.
Non-clinical carriers – Brook trout (Salvelinus fontinalis)	Faecal samples at 8–27 wpi and 76 wpi	3.0–3.9 $\log_{10}$ $TCID_{50}$/g, declining by 76 wpi	McAllister, P. E., & Owens, W. J. (1992). Infectious pancreatic necrosis virus in the environment: Relationship to effluent from fish hatcheries. Journal of Aquatic Animal Health, 4(4), 298–303.
Non-clinical carriers – Brook trout (Salvelinus fontinalis)	Reproductive products (milt, egg/ovarian fluid)	Milt: ~2.0–2.9 $\log_{10}$ $TCID_{50}$/mL (occasional high: 5.15); Egg/ovarian fluid: ~2.0–2.7 $\log_{10}$ $TCID_{50}$/g when detectable	McAllister, P. E., & Owens, W. J. (1992). Infectious pancreatic necrosis virus in the environment: Relationship to effluent from fish hatcheries. Journal of Aquatic Animal Health, 4(4), 298–303

In summary during clinical disease, tissue titres (notably pancreas) can spike to 10^7–10^8 $TCID_{50}$/g around peak mortality. Carrier fish typically harbour ~10^3–10^5 $TCID_{50}$/g in key organs (≈ 3–4.6 $\log_{10}$), often with intermittent shedding in faeces and low titres in reproductive fluids.

It is apparent that in carrier species between 1g and 100g of tissue would need to release its viral load into every mL of water, not suffer any dispersion or dilution and come into contact with a susceptible host.

The likelihood therefore of exposure of wild fish to sufficient virus to produce an infection is **extremely low.**

Consequence assessment

Mortality in birnavirus infected susceptible hosts is mainly restricted to larval and early juvenile stages, and disease does not necessarily occur in larger fish. Indeed, many fish experimentally infected with aquatic birnavirus can naturally resolve the infection provided they are healthy and remain unstressed (Reno 1999). Others remain carriers for life, and risk spreading birnavirus to their progeny vertically via infected gametes. Bivalves which concentrate birnavirus do not become diseased.

Given that aquabirnaviruses have already been reported from New Zealand's marine environment, and these viruses only tend to occur at subclinical levels in juvenile and adult fish in the wild (Anderson 1995, 1996, 1998, Wallace *et al*. 2008, McIntyre *et al*. 2010), the consequences of localized slight increases in prevalence of birnaviruses in wild fish and shellfish within 5 km of affected salmon farms (Wallace *et al*. 2008) appear related mainly to possible increased mortality of larval and early juvenile stages which, although never documented in wild fishes, could have some impact on wild fish at the population level. Considering all of these factors, establishment of the disease in cultured salmon would likely have minimal consequences, and would not cause any noticeable environmental effects. There would be negligible impacts on the health of flat oysters and their populations.

It is therefore estimated that the consequences of potential introduction of birnavirus strains into New Zealand's environment via salmon in sea pens in the Foveaux Strait would be **Very Low**.

Risk estimation

The release assessment concluded that likelihood of release via broodstock and input juveniles was ***negligible,*** while release from stock infected on the farm was **very low**. When we combine the highest likelihood (very low) with the exposure assessment of **extremely low** via the matrices above we get a combined released and exposure likelihood of **extremely low**.

With a consequence assessment of **very low**, when considered alongside the above combined release/exposure likelihood we get an overall risk rating of **negligible**.

As this is below the specified ALOP of very low, the unrestricted risk is acceptable and no specific risk mitigation measures are needed.

Infection with *Piscirickettsia* species

Aetiological agent

Gram negative, obligate intracellular gamma proteobacteria of the genus *Piscirickettsia* within the Family Piscirickettsiaceae.

Current status in New Zealand

Three strains of NZ-RLO have been identified, all related to *Piscirickettsia salmonis* (Brosnahan *et al.* 2017a, 2018, 2019b).

Reason for risk assessment

Piscirickettsiosis was first reported from coho salmon (*Oncorhynchus kisutch*) in Chile in the late 1980s, with mortality of up to 90% in affected farms, although mortality rates of 20-30% were more common.

Subsequently *P. salmonis* has been isolated from several other species of salmonids including Atlantic salmon (*Salmo salar*), chinook salmon (*O. tshawytscha*), rainbow trout (*O. mykiss*), pink salmon (*O. gorbuscha*), and cherry salmon (*O. masou*), as well as white sea bass (*Atactoscion noblis*), and European seabass (*Dicentrarchus labrax*), whilst closely related *P. salmonis*-like bacteria have also been isolated from grouper (*Epinephelus melanostigma*), muskellunge (*Esox masquinongy*) and tilapia (*Oreochromis* sp., *Tilapia* sp., *Sarotherodon* sp.), amongst others (Mauel and Miller 2002, DAFF 2013).

As this organism may cause significant disease, its history of mortality in Chile, and more recently in the Marlborough Sounds (Brosnahan *et al.* 2017a, Brosnahan 2020), and Tasmania, it is reasonable that it be subject to detailed risk assessment.

Release assessment

Rickettsia-like organisms occur in New Zealand waters, and may be found in non- or sub-clinical salmonid and non-salmonid carriers (Fryer & Hedrick 2003, Arkush *et al.* 2006). Infection is via direct horizontal transmission, or vertical via infected gametes.

Infection of a sea farm may primarily occur:

1. via introduction of infected juveniles as a result of vertical transmission from infected broodstock; or

2. Via horizontal infection on the sea farm post input from exposure to infected salmonid or non-salmonid fin fish, either wild or already present in a farming area.

The likelihood of smolt becoming horizontally infected in the freshwater hatchery before transfer is extremely low, due to the bacterium having very poor survival in freshwater (Lannan & Fryer 2006, Rozas & Enriquez 2014), but not negligible.

Once infection enters a farm population, horizontal transmission will occur within pen, and, more slowly, between pens via shedding of the bacterium via lesions, bile, faeces or urine and uptake in new hosts via skin, gills or intestine (Corbeil *et al.* 2019, DAFF 2013). Without disease management measures, especially treatment, the prevalence of infection is expected to increase across the farm. Mardones (2025) presented data to show an R_0 (Basic Reproductive Rate) of 1.7 (95%CI 1.6 – 1.9), meaning that peak prevalence would be 8.19 – 13.59%, which indicates moderate transmissibility with the risk of over spill of infection into wild salmonids, wild fish and potentially other farms (or from other farms) within 10km (Rees *et al.* 2014).

There have been no reports of the identification of rickettsia-like bacteria from South of Akaroa at the time of writing this report, however theoretically broodstock and juveniles may be sourced from any part of the South Island and so the risk exists.

The likelihood of infection in sea pens at Stewart Island is considered to be **Low** overall, as the more likely route via infected broodstock is a more complicated one. The direct route via infected wild fish is considered less likely at this time due to no reported findings in the area of the proposed farm.

Exposure assessment

The virulence and infectious dose of *Piscirickettsia*-like bacteria transmitted horizontally vary considerably depending on both the bacterial strain and the species being challenged. Experimental work by House *et al*. (1999) demonstrated this variability clearly. When coho salmon were injected with $10^{2.6}$ $TCID_{50}$ of a less-virulent Norwegian strain of *P. salmonis*, mortality rates were no different from those in unchallenged controls. In contrast, the same dose of a virulent Chilean strain produced mortalities exceeding 50%.

This difference is even more pronounced when comparing injection and immersion routes. Immersion challenges generally require much higher infectious doses to cause disease. For instance, Birkbeck *et al*. (2004) examined a *P. salmonis* strain with an LD_{50} in Atlantic salmon of less than 200 $TCID_{50}$ when delivered by injection. However, when fish were exposed by immersion to 10^5 $TCID_{50}$/mL for one hour at 14 °C, mortality reached only around 10%.

Given that New Zealand *Piscirickettsia*-like bacteria are related to *P. salmonis*, the evidence suggests it is unlikely that subclinically infected sea pen reared salmon would shed enough bacteria to achieve an immersion infectious dose in surrounding natural waters. The risk of horizontal transmission to wild fish, however, would increase substantially if pen reared salmon were to develop clinical disease, given the higher shedding rates observed under those conditions.

There is a clear transmission pathway from infected pend salmon into the marine environment. Shed bacteria could directly infect susceptible species of wild fish aggregating around sea pens, a behaviour well documented in studies such as Dempster *et al*. (2009). Given that susceptible hosts may be present in the immediate vicinity due to structural attraction and feed inputs, the overall risk of exposure and establishment is assessed as **Low** for subclinically infected salmon, but realistically rising to **Moderate** if the salmon are clinically diseased. The moderate rating is conservative, given that the majority of wild fishes are not considered susceptible; with wild salmonids being at primary risk.

Consequence assessment

Mortality linked to *Piscirickettsia*-like bacteria is generally confined to reports from farmed fish, typically in situations where other stressors predispose stock to disease. Reports of die-offs in wild fish are rare. A potential exception is an outbreak involving muskellunge and yellow perch in the United States (Thomas & Faisal, 2009), and an event in Hawaii where wild tilapia were observed with clinical disease and suspected to be the source of infection, though no other species were affected (Mauel *et al*., 2003). To date, there are no confirmed cases of these bacteria causing illness or mortality in wild marine fish or shellfish, including bivalve molluscs.

If the risk of exposure of wild fish to the New Zealand rickettsia-like organism (NZ-RLO) is not managed, its persistence in a wild reservoir population could result in ongoing infections in farmed populations which would impact the productivity and profitability of salmon aquaculture operations around Stewart Island and in Foveaux Strait. These bacteria are also notifiable in New Zealand and are currently under a containment notice (MPI, 2016).

Accordingly, the consequences of introduction of *Piscirickettsia*-like bacteria into the Foveaux Strait marine environment via sea-pen reared salmon are assessed as **Moderate**. To be clear, consequences for wild fish are considered generally low, but given the apparently free status currently and the potential for longer term damage to salmon aquaculture, it is appropriate to rank the consequence as moderate

Risk estimation

The release assessment concluded that likelihood of release was **Low**. When we combine that likelihood with the higher exposure assessment of **Moderate,** via the matrices above, we get a combined released and exposure likelihood of **Low**.

With a consequence assessment of **Moderate**, when combined with the above combined release/exposure likelihood we get an overall risk rating of **Low**.

As this is above the specified ALOP of very low, the unrestricted risk is unacceptable and specific risk mitigation measures are needed.

Infection with *Caligus* spp.

Aetiological agent

Sea lice affecting salmon aquaculture are marine ectoparasitic copepods in the family Caligidae, principally species of *Lepeophtheirus* and *Caligus*. *Lepeophtheirus salmonis* predominates in the Northern Hemisphere, while various *Caligus* spp. are of concern globally. In the Southern Hemisphere, key species reported from salmonid aquaculture include *Caligus rogercresseyi* (Chile) and *Caligus longirostris* (Australia). *Caligus* is a host-generalist reported from New Zealand waters on non-salmonid hosts (Hewitt 1963, Jones 1988) and has caused issues in northern aquaculture regions.

Current status in New Zealand

New Zealand farms predominantly King (Chinook) salmon, which show relative resistance to sea lice compared with Atlantic salmon. There are historical records of caligids in NZ waters, including small numbers of *Caligus longicaudatus* on sockeye salmon in sea pens, and the presence of *C. elongatus* on flatfish in the South Island. To date, sea lice have not been reported as a significant problem on cultured Chinook salmon in New Zealand.

Reason for risk assessment

In New Zealand, many marine fish species are natural hosts to copepod ectoparasites from the family Caligidae—commonly referred to as sea lice (Hewitt 1963; Jones 1988; Hine, Jones & Diggles 2000). These parasites initiate infection when their free-swimming copepodid larvae locate and attach to a suitable host. Upon attachment, they develop into chalimus larvae, which remain sedentary, anchored to the host by a frontal filament until moulting into mobile pre-adult and adult stages (Kabata 1984). At these later stages, lice may be found on the host's gills, skin, or fins, feeding on mucus, epidermal tissue, and blood (MacKenzie *et al*. 1998).

Sea lice infestations have been a major health challenge in salmonid aquaculture in several countries, contributing to disease outbreaks and significant stock losses (Pike & Wadsworth 1999). When infestations become heavy, host fish may experience chronic stress, reduced feeding, and increased vulnerability to secondary pathogens. Mortality is often linked to osmoregulatory collapse due to skin and gill damage, compounded by opportunistic bacterial infections (Grimnes & Jakobsen 1996; MacKenzie *et al*. 1998; Pike & Wadsworth 1999).

Given their direct life cycle, their capacity to cause direct tissue damage, physiological stress, and secondary disease, caligus lice represent a credible hazard in finfish aquaculture.

Release assessment

Given juvenile salmon (Smolt) will enter the farms direct from freshwater, they will not have caligus copepod infections at the time of sea pen entry. Therefore, the only route that farmed salmon in the Foveaux Strait can become infected is from wild fish or the water column. Once within the farm environment, with a direct life cycle and abundant hosts adjacent, there is potential for infection to amplify. In New Zealand waters, *Caligus* species are naturally present on multiple marine fish hosts (Hewitt 1963; Jones 1988; Hine, Jones & Diggles 2000), and are known to have low host specificity, thus there is potential for farmed salmon to act as amplifying reservoirs.

The release pathway for *Caligus* spp. from farmed Chinook salmon into the surrounding marine environment begins with the shedding of infective planktonic stages—principally nauplii and copepodids—directly from infected hosts. These larvae are released into the water column via normal parasite reproduction on the host, with ovigerous females capable of producing multiple egg strings over their lifespan (Kabata 1984; Boxaspen 2006).

The sedentary chalimus stage, which attaches to gills, skin, or fins (MacKenzie *et al*. 1998), develops into mobile pre-adults and adults capable of moving between hosts. Shedding of eggs from farm stocks can occur continuously, with release potential influenced by water temperature, host density, and parasite fecundity (Hamre *et al*. 2013). In high-density aquaculture conditions, lice reproduction is accelerated, and cumulative larval output can be substantial (Pike & Wadsworth 1999). Consequently, the release likelihood for caligus from infected farms into the surrounding environment is typically greater than for pathogens requiring complex life cycles or vector hosts.

Peer-reviewed modelling studies have demonstrated that even modest on-farm prevalence can seed high larval concentrations in surrounding waters, with dispersal distances dependent on local hydrodynamics (Krkošek *et al*. 2007; Costello 2006).

However, despite the clear potential pathways above, it is critical to consider that despite decades of culturing chinook salmon in New Zealand waters, at either end of the South Island, there is a lack of reports of sporadic, l*et* alone significant infection in farmed salmon, indicating that chinook salmon appear to have a significant resistance to caligus infection.

The release assessment is therefore considered to be **Very Low**.

Exposure assessment

Following release into the environment, Caligid copepodid larvae rely on a combination of passive drift and active host-seeking to locate susceptible fish. These larvae are positively phototactic and rheotactic, increasing encounter rates with fish moving through the water column (Hamre *et al*. 2013). The key exposure pathways for wild fish are direct attachment during planktonic drift or infection through close-range contact with infected farmed fish.

Critical factors affecting exposure probability include:

- Host density and distribution – High densities of wild pelagic fish, or wild salmonids migrating past farms, can result in high encounter probabilities (Krkošek *et al*. 2007).
- Environmental persistence – Copepodids can survive several days without a host, with survival duration dependent on temperature and salinity (Boxaspen 2006; Hamre *et al*. 2013).
- Infective dose thresholds – Laboratory trials show that even a low number of attached lice can cause stress and feeding reduction in juvenile salmonids (Grimnes & Jakobsen 1996), while heavier burdens increase morbidity and mortality risks.
- Hydrodynamic transport – Oceanographic models demonstrate larval drift from farms can expose fish many kilometres away, even in complex coastal systems (Costello 2006).

Given that *Caligus* species are generalist ectoparasites capable of infesting multiple host species, exposure potential extends beyond salmonids to other marine finfish (MacKenzie *et al*. 1998). In areas where farms operate near migratory corridors or high-value wild fisheries, the likelihood of exposure is considered to be **Moderate**.

Consequence assessment

The establishment of Caligus in a susceptible host population can result in significant biological, economic, and ecological consequences. Heavy infestations damage skin and gill tissues, impair osmoregulation, and facilitate opportunistic bacterial infections (Grimnes & Jakobsen 1996; MacKenzie *et al*. 1998). In farmed salmonids, such infestations have been linked to reduced growth, increased feed conversion ratios, and mortality events (Pike & Wadsworth 1999; Treasurer & Bravo 2011).

In wild fish populations, Caligus outbreaks associated with proximity to salmon farms have been implicated in declines of juvenile salmon survival during outmigration

(Krkošek *et al*. 2007). Ecological consequences may include shifts in predator-prey dynamics, altered migration success, and changes in species composition where infestations are severe or recurrent.

Economic impacts on aquaculture are well-documented, with treatment costs, production losses, and market effects cumulatively reducing profitability (Costello 2006; Treasurer & Bravo 2011).

However, given that these parasites already exist within the local environment, the risk lies not in the introduction of a new hazard, but in an incremental increase in prevalence on wild fish. Given that sea lice associated with sea-pend salmonids typically occur at subclinical levels in wild non-salmonid hosts (Jones *et al*. 2006a, 2006b), any localised elevation in prevalence or intensity of infestations in wild fish near affected salmon farms is assessed as unlikely to result in measurable adverse effects on native fish population health or sustainability.

The consequence is therefore assessed as **Low**.

Risk estimate

The release assessment concluded that likelihood of release was **Very Low**. When we combine that likelihood with the higher exposure assessment of **Moderate,** via the matrices above, we get a combined released and exposure likelihood of **Very Low**.

With a consequence assessment of **Low**, when combined with the above combined release/exposure likelihood we get an overall risk rating of **Negligible**.

As this is below the specified ALOP of very low, the unrestricted risk is acceptable and no specific risk mitigation measures are needed.

Infection with *Bonamia* spp.

Aetiological agent

Bonamia exitiosa and *Bonamia ostreae* are small (2–3 µm) protozoan parasites within the phylum Cercozoa, order Haplosporida, that infect flat oysters by targeting their agranular haemocytes (Hine 1996, Reece *et al*. 2004, Engelsma *et al*. 2014). Both species have a direct life cycle, transmitting from oyster to oyster via waterborne uninucleate microcells released in faeces, urine, gametes, across gill surfaces, and from the tissues of moribund or dead hosts. Once inside haemocytes, they resist lysis, multiply, and ultimately cause the haemocytes to rupture, releasing new infective cells into the surrounding tissues (Hine 1991a, 1991b).

B. exitiosa is a host generalist, recorded in at least seven flat and cupped oyster species globally (Hill *et al*. 2014), while B. ostreae is more host-specific, historically associated with Ostrea edulis in Europe (Hill *et al*. 2014) but also detected in *O. chilensis* in New Zealand (Lane *et al*. 2016). The differences in host range influence their potential impacts and epidemiology, but both can cause devastating disease in naïve populations, particularly when environmental or anthropogenic stressors reduce host resilience.

Current status in New Zealand

B. exitiosa was first described from Bluff oysters (*O. chilensis*) in Foveaux Strait (Hine *et al*. 2001, Berthe & Hine 2003) but retrospective analyses indicate its likely involvement in epizootics dating back to the early 1960s (Cranfield *et al*. 2005). Since then, it has become established in Foveaux Strait, the Marlborough Sounds, and the Hauraki Gulf (Lane *et al*. 2018). The Foveaux Strait populations experience recurring mortality events, making the parasite a central driver of oyster stock dynamics.

In contrast, *B. ostreae* was not detected in New Zealand until January 2015, when it was found during mortality events in farmed *O. chilensis* in the Marlborough Sounds area and in a land-based aquaculture facility in Nelson (Lane *et al*. 2016, 2018). In May 2017, it was detected in two oyster farms in Big Glory Bay, Stewart Island (MPI 2017a, 2017b). In both regions, prevalence was high, often exceeding 95% in affected farms, and *B. ostreae* frequently occurred alongside *B. exitiosa* in mixed infections (Lane 2018). All affected farms have since been depopulated. To limit further spread, a Controlled Area Notice was implemented, restricting movements of oysters, other bivalves, and equipment from or to the Marlborough Sounds, Nelson, and Stewart Island (MPI 2017b, 2018). Intensive surveillance to date has found no evidence of B. ostreae in wild Bluff oysters in Foveaux Strait (MPI 2017b, NIWA 2017). However, a recent report (Santoro 2024) highlights that the parasite is moving towards the Foveaux Strait despite the restrictions, and is expected to enter the Eastern aspect of the Strait flat oyster populations by 2026–2030. Once *B. ostreae* spreads into Foveaux Strait, it is predicted to spread at a speed of 2.5–5 km per year, westwards. So that it is estimated to spread through the whole oyster population within the core commercial fishery area within 7–14 years.

Reason for risk assessment

B. exitiosa has caused repeated large-scale mortality events in Bluff oysters, with major epizootics between 1985–1992 and 1999–2004 reducing oyster stocks in Foveaux Strait to less than 9% of pre-disease levels (Dinamani *et al*. 1987, Cranfield *et al*. 2005, Michael *et al*. 2015, 2017). The earliest suspected outbreak occurred in the early 1960s, initially attributed to *B. longicornutus*, but later reinterpreted as likely caused by *B. exitiosa* (Hine & Jones 1994, Hine 1996, 1997). These events often spread as waves of infection moving from west to east along prevailing tidal flows, sometimes taking years to pass through the entire fishery (Hine & Jones 1994, Cranfield *et al*. 2005).

The infection cycle intensifies during the post-spawning period, particularly February to April, when gonad resorption coincides with elevated parasite proliferation (Hine 1991a, 1991b). Terminally infected oysters can contain around 5×10^8 microcells (Diggles & Hine 2002, Cranfield *et al*. 2005), far exceeding the estimated 18-week LD_{50} of 1.1×10^5 microcells for *B. exitiosa* and comparable to lethal doses for *B. ostreae* (Hervio *et al*. 1995, Arzul *et al*. 2009). Infective particles can survive at least 2–4 days in seawater (Arzul *et al*. 2009) and longer under favourable conditions. Laboratory studies show that high-density holding, environmental stress, and mechanical disturbance can accelerate transmission (Hine *et al*. 2002).

B. ostreae, historically restricted to Europe and North America, has been responsible for severe declines in O. edulis production in France and other countries following spread via oyster translocation (Elston *et al*. 1986, Laing *et al*. 2014). Its emergence in New Zealand represents a serious threat to *O. chilensis*, especially given the high mortalities observed in Marlborough Sounds farms, often approaching 100% (Lane 2018a). Mixed infections with *B. exitiosa* may further increase pathogenicity. Both species can spread via live oyster movements, transport of other filter-feeding bivalves, and biofouling on vessel hulls and aquaculture equipment (Howard 1994, Bishop *et al*. 2006, Deveney *et al*. 2017), with biofouling acting as a potential long-distance vector between regions.

Release assessment

Both *Bonamia* spp. shed infective microcells continuously from infected hosts, with moribund oysters releasing particularly large numbers. For *B. exitiosa*, a single terminally infected oyster can release enough microcells to theoretically kill thousands of nearby oysters (Diggles & Hine 2002, Cranfield et al. 2005). Similar shedding patterns are observed in *B. ostreae* infections (Arzul et al. 2009). Infective stages are efficiently captured by filter-feeding bivalves, including non-host carriers such as mussels, which may retain viable parasites and facilitate their transfer to susceptible oyster populations (Ford & Tripp 2009). Aquaculture infrastructure such as salmon pens, moorings, and service vessels can host biofouling communities that may include infected oysters or other bivalves. Without effective and frequent biofouling control, these structures could act as reservoirs from which infective particles are released into surrounding waters. Increased vessel activity to service large offshore farms raises the risk of introducing infected biofouling from other regions. Despite existing biosecurity measures, vessel-mediated spread remains a recognised pathway, as demonstrated by past incursions of *B. ostreae* into new areas (MPI 2017b, 2018).

For the farms to represent increased risk to the environment, the farms must develop biofouling which in itself must become infected with Bonamia. Flat oyster biofouling is the principal risk as those animals could, if left on the farm in large numbers, succumb to the infection when they become sexually mature and spawn, thus releasing large quantities of infectious particles. Infection could come from benthic flat oysters or from fouled vessels, barges etc. at the farm site.

Studies indicate that flat oysters suspended in the water column (e.g. on culture lines or hull fouling) often show lower Bonamia infection rates compared to seabed populations. In Europe, moving *Ostrea edulis* from seabed culture to suspension culture has been recommended to reduce bonamiosis outbreaks (Tigé *et al.* 1984). Raft-grown European oysters kept near the surface (1–2 m depth) exhibited significantly lower Bonamia prevalence and mortality than cohorts held deeper near the seafloor (8–9 m depth), implicating proximity to the benthos as a risk factor (Lama & Montes 1993).

The release assessment for both species is non-negligible and is considered to be **Moderate** for *B. exitiosa* and *B. ostreae*.

Exposure assessment

There could be incremental increase in exposure of oysters in Foveaux Strait to *Bonamia* spp. if infective particles are transported from biofouling reservoirs on farming structures primarily (Bulleri & Airoldi 2005). Historical *B. exitiosa* outbreaks demonstrate that disease fronts can move progressively across the fishery, following residual tidal flows (Cranfield *et al*. 2005). The critical density threshold for triggering an epizootic is about 1.26 oysters/m^2 (Doonan *et al*. 1999), which is exceeded in some local beds, even where densities are insufficient for commercial harvesting. Once established, both species can spread amongst oysters in close proximity. Exposure to benthic beds of flat oysters would be via settlement of infected larvae, or the sinking of detritus from dead fouling oysters. The exposure likelihood is moderated somewhat by the farm structures being placed over benthos that is less suitable for the flat oysters.

The exposure assessment is considered to be **Moderate** for both species.

Consequence assessment

B. exitiosa is already a principal driver of oyster population dynamics in Foveaux Strait, with repeated epizootics causing severe declines and long recovery times. Habitat changes from dredging have reduced populations of other filter-feeding organisms, limiting the natural removal of infective particles and increasing the vulnerability of oyster beds (Cranfield *et al*. 1999, 2003, 2005).

Introduction of *B. ostreae* to Foveaux Strait would add a second, highly pathogenic parasite to an already stressed system, in advance of the expected timeline (Santoro 2024). In naïve *O. chilensis* populations, it could cause high mortality, irreversible stock declines, and potential collapse of the commercial fishery. Mixed infections could exacerbate mortality beyond levels seen for either parasite alone. Ecologically, further loss of biogenic reef habitat would reduce biodiversity and ecosystem resilience. Economically, sustained low oyster abundance would threaten the viability of the Bluff oyster fishery and associated industries. While impacts of *B. exitiosa* might be reduced if stressors were removed, *B. ostreae* is likely to persist indefinitely once established.

The consequence assessment for *B. exitiosa* is considered to be **Moderate** and for *B. ostreae*, **High**.

Risk estimate

For *B. exitiosa*, the likelihood of release and exposure is Low, with Moderate consequences, giving a **Low** overall risk. For *B. ostreae*, the likelihood of release and exposure is Low but the consequences are High, giving a **Moderate** overall risk. Combined, the presence or introduction of *Bonamia* spp. in relation to Bluff oysters in Foveaux Strait presents a risk above the ALOP, requiring proactive management to reduce introduction and spread pathways.

In the case of *B. ostreae*, these risk mitigations are to slow the, already considered likely, spread of the parasite from the Eastern aspect of the Strait.

Risk Mitigation Options

The detailed risk assessments have concluded that risk mitigation options are appropriate for:

Piscirickettsia spp. (including NZRLO)

And

Bonamia spp.

Piscirickettsia species

Effective risk mitigation for piscirickettsiosis requires a multilayered approach across all stages of production: Hatchery (freshwater), pre-transfer & transport, marine stocking & early grow-out, and vaccination & therapeutics. The strategy is prioritized by the risk pathway – i.e. first, *keep it out* (prevention at hatchery and transfer levels), second, *reduce susceptibility* (vaccination, stress reduction before and just after sea entry), and third, *early detection and rapid response* (to contain any infection). In addition, best practice management reduces stress and maintains best health status throughout the growing period. Using this strategy, the risk is expected to be managed to an **extremely low** risk.

Hatchery (Freshwater) Biosecurity Measures

1. Smolt Source Selection & Auditing: *Only stock smolt from hatcheries with high biosecurity standards and no history of RLO, or where each population of smolt is tested to be clear of RLO using a statistically significant sample size designed to detect 2% prevalence with 95% confidence.* Hatcheries in regions where *Piscirickettsia* has been detected in seawater (e.g. Marlborough) should demonstrate extra safeguards (secure freshwater sources without wild salmonids, testing), alternatively hatcheries in regions where neither NZRLO1 nor 2 has been detected should be used. *Effect:* High – utilising a pathogen-free source is the single most effective way to prevent introduction. *Feasibility:* High – NZ has a small number of salmon smolt suppliers, all can be assessed. *Residual risk:* Very low (but not zero, hence the below measures). Regular audits (at least annual) will verify continued freedom.

2. Broodstock Management: *Use broodstock and ova that are free from* Piscirickettsia. *This involves two practices: (a) keeping broodstock in freshwater their entire life (never transferring brood fish to sea pens, thus eliminating exposure to marine pathogens); and (b) screening broodstock for P. salmonis via PCR prior to, or at, spawning*. Any broodstock that spent time in Marlborough sea pens, for example, would be excluded. In addition, surface-disinfect all eggs with iodophor, acknowledging it would be ineffective against internal bacteria (intra-ovum *P. salmonis* may occur according to Larenas *et al.* (2003)) but it does remove surface contamination. *Effect:* High – this tackles the vertical transmission route. While vertical transfer is not the main driver, it is one potential conveyor for the bacterium. *Feasibility:* High – NZ hatcheries already handle broodstock in freshwater; and testing is straightforward. *Cost:* Low – PCR testing brood fish and egg disinfection is inexpensive relative to the crop value. *Prerequisites:* Validated PCR assay that can detect NZ-RLO strains in gonad fluid (MPI has one as of 2015). *Residual risk:* Negligible – the chance of a vertically infected smolt after these steps is extremely low, below 1–2% probability.

3. Hatchery Water Biosecurity: *Ensure the hatchery water supply is free from marine intrusions or contamination*. Since *P. salmonis* does not survive long in freshwater, the main risk would be via wild marine salmonids entering the hatchery or an unusual event like seawater backflow or perhaps introduction via equipment. Preferably use bore or spring water (as many NZ hatcheries do) and have physical structures that prevent wild salmonids entering the hatchery. *Effect:* Moderate – direct marine contamination of a land-based hatchery is unlikely, but this measure addresses any residual pathway. *Feasibility:* High – Moderate depending on the hatchery. *Cost:* Low (if already secure) to moderate (if new exclusion infrastructure needed). *Prerequisite:* None: *Residual risk:* Very low.

4. Routine Health Surveillance in Hatchery: *Implement a screening program for broodstock and juveniles.* This means at key points (e.g. before smolt are transferred) testing a sample of fish for *P. salmonis* by qPCR. The rationale is to catch any subclinical or carrier *Piscirickettsia* infection at low prevalence. NZ's Animal Health Lab has developed a sensitive qPCR able to detect NZ-RLO strains; using a sample size that gives 95% confidence to detect 1–2% prevalence ensures a robust check. *Effect:* High – this ensures *P.* salmonis-free broodstock and provides assurance that smolt are not sub-clinically infected. *Feasibility:* High – animal numbers mean sample sizes are easily accommodated, and rapid qPCR testing is available *Cost:* Moderate – PCR testing costs are relatively low and easily justified. *Prerequisites:* Available lab capacity and sampling protocols. *Residual risk:* If tests are all negative, the probability of undetected infection in the batch is extremely low.

5. Biosecurity Barriers & Hygiene in Hatchery: *Maintain strict hatchery biosecurity to prevent pathogen entry via people, equipment, or wild vectors.* This includes footbaths and equipment disinfection for visitors, dedicated gear per facility (or thorough disinfection between uses), and pest control (keeping wild fish or birds out of hatchery water). Staff should adhere to biosecurity protocols, especially if they travel between hatcheries or farms – ideally no direct personnel movement from marine farms back to hatchery without decontamination (e.g. gear and clothing). Any eggs imported or transferred between sites should have health certification. *Effect:* Moderate – these measures address indirect introduction routes. For *P. salmonis*, the biggest risk would be someone inadvertently bringing contaminated seawater or fish material into the hatchery. Good biosecurity will lower that risk substantially. *Feasibility:* High – these practices are standard in modern aquaculture. *Cost:* Low – mostly procedural (training, disinfectants, etc.). *Prerequisites:* Management commitment and regular biosecurity audits. *Residual risk:* Low – cannot be zero because human error is possible, but with a strong biosecurity culture, the hatchery should remain a specific pathogen-free compartment.

Pre-Transfer & Transport Mitigations

This phase covers the period from preparing smolt for shipment, through the journey, up to the point of releasing into sea pens. The focus is on minimizing stress (to keep fish healthy and resistant) and avoiding any contamination during the transfer process.

1. Pre-transfer Health Check & Certification: Up to 4 weeks before a veterinarian should perform a health inspection. This includes examining a sample of fish for any signs of disease, verifying lab test results (from the hatchery surveillance above), and issuing a health certificate. The certificate would confirm the batch has no clinical signs of *Piscirickettsia*-related illness and has tested negative by PCR (with details on sample size and test sensitivity). *Effect:* Moderate – whilst sampling what is presumably a healthy population for testing is of limited sensitivity, the procedure does allow for a clinical assessment of the population. *Feasibility:* High – already standard practice for moving stock in most salmonid jurisdictions. *Cost:* Low (veterinary time and examination costs).

2. Controlled Smolt Loading: When loading smolt for transport, handle them in a gentle and biosecure manner. Use clean, disinfected equipment. Ideally, crowd fish gently and pump them into the transport tank rather than excessive net handling. Maintain low loading densities in transport (e.g. if using a tanker truck, do not exceed densities recommended for salmon transport, typically ~60–80 kg/m^3 with oxygenation). *Effect:* Moderate – gentle handling reduces stress responses like cortisol spikes that can suppress immune function for days. It also minimizes physical injuries that could become entry points for bacteria. The benefit is fish arrive at the sea site in better condition and will be more resilient to any pathogen exposure. *Feasibility:* High – requires training staff in best handling practice. *Cost:* Low (simple operational care).

3. Temperature and Oxygen Control During Transport: Ensure transport water is at an optimal temperature (likely the same as the hatchery water, often ~10–12 °C, which is cooler than ambient air) and highly oxygenated. Using constant oxygen monitoring and supplementation is required will keep fish from experiencing hypoxic stress. *Effect:* Moderate – Fish that are transported in ideal water conditions won't be as immunocompromised. High oxygen is crucial; even mild dips in oxygen can stress fish significantly. Susceptibility to piscirickettsia has been linked to exposure to low oxygen events. *Feasibility:* High – standard for fish transport. *Cost:* Moderate for initial tanker setup where monitoring and oxygenation systems are not already present.

4. Biosecure Transport Water: Use fresh, pathogen-free water in transport tanks (e.g. filtered fresh water or bore water, or UV-treated freshwater). Do *not* use seawater for transporting smolt, as that could compromise the biosecurity of the hatchery. *Effect:* Moderate – This measure prevents contamination of the freshwater site. *Feasibility:* High – this setup of tankers is common. *Cost:* Low

5. Transport Equipment Disinfection: Prior to and after use, clean and disinfect all transport tanks, fish pumps, pipes, nets, and containers that will contact the smolt or water. Effective disinfectants include iodophors, chlorine, or peracetic acid at appropriate concentrations (with sufficient contact time to kill *P. salmonis*). Peracetic acid or virkon aquatic would be compounds of choice. Pay special attention to any surfaces that may harbour biofilms. *Effect:* High – ensures no residual pathogen from previous operations is present. For example, if the smolt truck last hauled fish from Marlborough, thorough disinfection prevents cross-contamination. *Feasibility:* High – well within standard biosecurity practice. *Cost:* Low. *Residual risk:* Virtually none if cleaning is done properly, given *P. salmonis* doesn't form spores and is susceptible to disinfectants.

7. Receiving Protocol at Sea Site: At the marine farm, farm staff receiving the smolt should inspect the fish as they go in – looking for any abnormal behavior or mortalities in transit. Remove any moribund or dead fish promptly (and bag them for potential diagnostic testing). This heightened scrutiny at arrival is designed to detect issues immediately to allow investigation and correction. *Effect:* Moderate – early detection potential. *Feasibility:* High. *Cost:* Low.

8. Stress Reduction at Stocking: Employ techniques like gradual acclimation to full strength seawater for at least an hour and a half. While not specific to *P. salmonis*, reducing stress means the fish's immune system remains robust. Consider extra vitamins or immunostimulants before and after transfer to sea. *Effect:* Moderate – a less stressed fish is less likely to succumb to any initial pathogen exposure. *Feasibility:* High - gradual acclimation of smolt is already established in the industry and equipment simply consists of a pump and some pipework. *Cost:* Low.

Marine Stocking & Grow-out Measures

The first 3–4 months of grow-out has been identified as the most vulnerable period, but piscririckettsia can occur in any size of fish. The objectives are to minimize conditions that favour *Piscirickettsia* infection, detect any issue as early as possible, and prevent spread between pens to as great a degree as possible.

1. Optimal Site Selection & Hydrodynamics: This mitigation was in fact addressed by site choice – the new farm is offshore of Stewart Island with good water exchange and depth, and cooler waters. It has already been noted that *Piscirickettsia* outbreaks in NZ correlate with poor water flow sites (Brosnahan *et al.* 2018, Gias *et al.* 2018). A well-flushed site dilutes any bacterial load and also provides better oxygen and temperature stability. So, *as a mitigation*, ensuring pens are located where currents disperse particles. *Effect:* High – site characteristics (flow, depth, temperature) partially explain why Stewart Island farms have avoided RLO. *Feasibility:* Already done (site chosen). *Cost:* N/A (design phase). *Residual risk:* Low, though note that good flow may spread pathogens farther if an outbreak isn't contained – hence need other measures too.

2. Stocking Limits: There are no studies that indicate classical stocking density (kg/m^3) is correlated with piscirickettsiosis, however it is good practice to limit stocking numbers per pen and it is advisable to stock smolt pens only at numbers that can be split down into two grow out pens. *Effect:* High – stocking number is a controllable factor. *Feasibility:* High – directly under control of the farmer. *Cost:* Potential minor reduction in production potential, but likely offset by better survival.

3. Single-Year-Class Strategy: Stock each "farm" with one cohort of smolt at a time and do not add new younger fish into pens containing older fish. This "all-in, all-out" principle is to avoid mixing naïve fish with potential carrier fish that have survived an earlier infection. *Effect:* High – prevents an ongoing reservoir in older fish that could keep infecting successive batches. *Feasibility:* High – requires planning farm production cycles accordingly. *Cost:* Low (just management practice).

4. Fallowing and Site Rotation: After each generation of salmon is harvested, leave the site fallow (no fish) for a minimum period (some countries recommend 3 months, but it should be no less than 2) before restocking. Price *et al.* (2017) retrospectively assessed fallow period performance in Chilean outbreaks of piscririckettsiosis and concluded that fallow periods of 1 month were insufficient, and that extending periods over 3 months had no advantage. This resulted in better clinical performance in the next cycle, but the likelihood was still very high of detecting the bacterium. Olivares and Marshall (2010) used environmental DNA monitoring to determine that no residual nucleic acids of *P. salmonis* were detectable after 49 days, whilst Levipan *et al.* (2020) noted a 14-30 day free-living survival of the bacterium . A two to three month fallow period therefore allows any *P. salmonis* in the environment to die off naturally. *Effect:* High – fallowing is proven effective for many pathogens and given *P. salmonis* limited persistence, it does reduce early onset piscirickettsiosis. *Feasibility:* Moderate – requires production scheduling to allow fallowing. For multi-farm companies, fish can be rotated. For a single site, it means not immediately restocking after harvest. Could incur production inefficiency. *Cost:* Moderate – because of lost opportunity during fallow.

5. Enhanced Biofouling Management: Implement a robust net cleaning regime and/or use of antifouling technology to prevent heavy biofouling. *P. salmonis* can form biofilms on mussels and other fouling organisms (Levipan *et al.* 2020). Frequent net cleaning (in-situ mechanical cleaning, preferably with vacuum removal of net plumes) will remove potential bacterial reservoirs and sources of skin and gill damage that may permit *Piscrickiettsia* spp. to enter the fish. Additionally, cleaner nets improve water flow and fish health. *Effect:* Moderate – reduces environmental pathogen accumulation. *Feasibility:* High – requires equipment (net cleaners or spare nets) and procedures. NZ farms do have to manage biofouling due to other concerns (weight, oxygen). *Cost:* Moderate – net cleaning is labor and equipment intensive. *Prerequisite:* Ensure that cleaning does not adversely affect fish – e.g. vacuum plume removal as an adjunct.

6. Husbandry for Stress Reduction: Maintain best practice husbandry: feed the fish a high-quality diet (with perhaps supplements like vitamin C, E, and beta-glucans for immune support), and remove mortalities promptly every day. Mort removal is critical – a dead fish decomposing in the net releases *Piscirickettsia* bacteria, greatly increasing exposure to conspecifics. Therefore, use mort retrieval systems or divers daily during higher risk periods i.e. late spring, summer and early autumn. Also, minimize handling – no unnecessary grading or moving fish during the first 1-2 months. *Effect:* High – Good general husbandry has a well-documented effect on reducing disease outbreaks. *Feasibility:* High – This is within farm management control. *Cost:* Low to moderate (maybe slight cost for better feed or additive, and capex or labour for mort collection).

7. Early-Warning Surveillance Program: Implement a structured health surveillance program on the farm:
- **Daily**: Farm staff perform pen observations for behaviour changes (fish off-feed, lethargic, surface swimming) and record mortality counts from each pen. Any abnormal mortality (above baseline, e.g. >0.05%/day) triggers inspection of the dead fish for signs (septicaemic signs, liver lesions or skin lesions) and notification to the farm veterinarian.
- **Weekly**: A more thorough health check: sample a few fish from each pen (including any that look weaker or have lesions) for clinical exam. This might involve euthanizing 2-3 fish from different pens to necropsy and check internally for any pathognomic signs of piscirickettsiosis.
- **Periodic Scheduled PCR**: For example, at 2 weeks post-transfer, 6 weeks, and 10 weeks, sacrifice or swab a sample of fish (e.g. 10 per pen, or pooling swabs) and run *P. salmonis* qPCR even if they appear healthy. This proactive testing could catch a low-level infection before it results in increasing numbers of clinically diseased fish.
- **Data analysis**: All health, feeding and environmental data (temp, oxygen, mortalities) are analysed to look for trends.

Effect: Very High – early detection is arguably the most important mitigation for containing an outbreak. If a few fish are detected with infection when mortalities are still low, interventions (like antibiotics, isolation) can be applied to prevent a full-blown epidemic. House *et al.* (1999) and Birkbeck (2004) studies showed fish need a substantial dose via water to become infected; catching and removing infected fish early can keep exposure to conspecifics below that threshold. *Feasibility:* Moderate to High –requires resource commitment and lab support. *Cost:* Moderate – necropsy and testing will incur lab costs regularly. But those are minor compared to potential losses if missed. *Residual risk:* Low. Ideally, time-to-detection (from infection introduction) would be kept minimal.

8. Feed Additives (Immunostimulants/Probiotics): As a preventive, some farms incorporate functional feed ingredients that may bolster fish immunity or gut health.

Examples: beta-glucans from yeast or algal extracts can enhance macrophage activity; Omega-3 HUFA-rich diets reduce inflammation; probiotics (beneficial bacteria) in feed can outcompete pathogens in the gut or secrete antimicrobial compounds. While specific evidence against *P. salmonis* is not robust, Chilean farms have tried immunostimulant feeds with some success in improving survival rates during SRS outbreaks (sometimes these are used in synergy with vaccination to improve immune response)(Evensen *et al.* 2016). *Effect:* Uncertain/Low to Moderate – tank trials support their use, but commercial applicability is still being assessed. *Feasibility:* High – commercial feeds with additives are available. *Cost:* Moderate – such feeds are more expensive. *Prerequisites:* availability of health packs from feed manufacturers.

Vaccination & Therapeutics

This section addresses specific medical interventions: vaccines to prevent disease, and treatments (antibiotics, etc.) to control it if it occurs.

1. Vaccination Program: If a commercial efficacious vaccine becomes available, v*accinate all smolt against* Piscirickettsia prior to sea transfer**.** Currently, there is no off-the-shelf commercial vaccine in NZ for NZ-RLO. A suitable vaccination schedule would be intraperitoneal injection of smolt 4–6 weeks before sea transfer. *Effect:* High – an efficacious vaccine can reduce disease incidence and severity. In Chile, vaccination alone has not eliminated piscirickettsiosis, but farms with vaccination have seen lower losses and delayed onset of outbreaks (Evensen 2016). Given NZ's specific strains, the autogenous approach is prudent – it ensures strain coverage, but genomic phylogeny could be assessed to determine if Australian or Chilean vaccines might be efficacious. *Feasibility:* Moderate – injection vaccination of large numbers of smolt is labor-intensive but standard. *Cost:* Moderate– manufacturing an autogenous vaccine and injecting fish is a significant cost. However, compared to potential losses, it's justified. *Prerequisites:* Access to pathogen strain, license to manufacture autogenous vaccine for on-farm use, and trained staff to vaccinate or automated vaccination machines. *Residual risk:* Vaccines are not 100% effective; some fish may still get infected but likely in a milder form (giving time to respond). With vaccination, the likelihood of a severe outbreak is reduced.

2. Antibiotic Therapies: If an outbreak occurs despite prevention, antibiotic treatment is the main remedial measure to reduce mortality. Common antibiotics effective against *P. salmonis* include oxytetracycline and florfenicol, administered through medicated feed, or rarely by injection. In NZ, use of antibiotics in salmon must be prescribed by a veterinarian. However, contingency plans should list which antibiotics are permitted and effective. Florfenicol has been used internationally with success against piscirickettsiosis (reducing mortalities). NZ's isolated cases likely remain highly susceptible to florfenicol. *Effect:* Moderate – antibiotics can curtail an outbreak if started early in the infection curve, but often do not eradicate *P. salmonis* from carriers and may not save moribund fish. *Feasibility:* Moderate – must deliver the medicated feed whilse feed response is still good (appetite will become depressed during infection). *Cost:* Moderate – antibiotics themselves aren't extremely expensive for fish, but any antibiotic use has a cost in possible trade restrictions and having to observe withdrawal times (which could disrupt harvest schedules). *Stewardship:* Ensure only approved antibiotics are used and follow withdrawal period so no residues in harvested fish. Also, use sensitivity testing to monitor farm rickettsial populations for resistance development.

3. Immunostimulants: As mentioned in husbandry, we can include immunostimulant compounds (like beta-glucans, nucleotides, etc.) in feed especially during high-risk periods (transfer, summer). Another preventive measure could be vaccinating against other diseases that might co-infect e.g., ensure fish are vaccinated for *Yersinia ruckeri* if any risk, as co-infection can worsen outcomes. *Effect:* Low but contributes to resilience.

Bonamia ostreae & *B. exitiosa*

The **pathogen risk assessment** noted there was a **moderate** risk of increased *Bonamia ostreae* and a **low** risk of increased *Bonamia exitiosa* propagule pressure if flat oysters or other bivalve shellfish were permitted to build up on the farming structures. Ascidians (*Styela clava*) have been implicated as a reservoir of *Bonamia ostreae* infection, although Costello *et al.* (2020) demonstrated that ascidians cohabitant with infected oysters showed a reduced infection prevalence in the presence of infected flat oysters. This indicates that there is ambivalent evidence of the role of ascidian species in the propagation of *Bonamia ostreae*, especially when there is limited domestic regulation to control all the other potential pathways.

This risk will be managed to an **extremely low** risk via management of the biofouling on the farming structures and through the placement of the farming structures over areas of the benthos which indicate maximal sea bed shear forces, sandy substrate and environments not conducive to the survival of bivalves.

It is recognized that *Bonamia* spp. may affect a wide age range of oysters, including larvae (Arzul *et al*. 2009), 6-month oysters (Lynch *et al.* 2005), but with maximum infection pressure and susceptibility in oysters in excess of 50mm diameter (Fu *et al.* 2016). Maximum infection pressure is a result of mortality and the shedding of infectious particles and body debris from dead oysters. The BMP therefore seeks to minimize the presence of oysters >50mm or 2+ year (whichever is sooner) on the farm.

In considering biofouling risk, we note that in the area of Stewart Island the majority of mussel fouling would occur post spawning in March to June (Key, 2001), and flat oyster settlement primarily in October to January (Michael, 2019). The highest risk of significant *Bonamia* spp. propagule pressure is from moribund and dead spawned oysters of 2+ age category, however established mussel biofouling has also been implicated as a risk (Howard 1994, Bishop *et al*. 2006, Deveney *et al*. 2017). It is therefore reasonable to minimize the presence of such older oysters and large mussels. In planning this we consider the spawning and settlement periods of these molluscs

Seasonal Calendar (Jan–Dec) – Spatfall vs. Growth Timeline

The yearly cycle of growth, maturation, spawning and settlement assists in identifying when risk management measures should be applied.

The table below summarizes, for each month in Foveaux Strait, the relative likelihood of *O. chilensis* larval release and spat settlement (qualitative low/medium/high, based on historical observations), alongside the growth stage progression of oysters on farm structures under typical conditions (assuming average seasonal sea temperatures and food availability). Peak spawning/spatfall periods and critical growth milestones are highlighted. (Note: "year-class" in growth refers to oysters that settled in the previous peak spatfall season.)

Month	Larval Release & Spatfall (Foveaux Strait)	Oyster Growth Stage Progression (on structures)
January	**High** (late summer spawning still ongoing, though declining) – Many brooding oysters are releasing larvae through early January (Brown *et al.* 2010, Michael & Shima 2018). Settlement of spat remains **high** on available substrates, tapering by late Jan as broodstock condition wanes.	Young-of-year spat from spring are now 3–5 months old, growing actively in warmest water (~14 °C). These spat reach 10–20 mm by end of summer (rapid growth phase) (Michael 2019). Older juveniles (settled last summer) may reach 30–40 mm by now, with some entering first male maturity.
February	**Low** – Main spawning season ending. Few new larvae released; most adults have either spawned or are in post-spawn recovery by Feb. Any late spatfall is minimal.	Spat growth slows as food declines. Year-1 juveniles (settled spring) now 15–25 mm. **Post-spawning adults** on structures (if any remained) are in weakened condition, with *Bonamia* infections peaking; high mortality risk in Feb–Mar.
March	**Minimal** – Virtually no spawning; oysters are resorbing gonads. Larval presence in water is near zero until next spring (Michael & Shima 2018).	Little to no new settlement. Growth nearly ceases as warm season ends. Young juveniles enter a maintenance phase (20–30 mm size). Any adults present are likely dying off from Bonamia by late summer (new "clocks" – fresh shells – observed Mar–Apr in disease years).

April	**None** – **No spawning**; oysters dormant reproductively. No larvae in plankton.	Cooler waters (~11–12 °C) halt growth. First-year juveniles remain 20–30 mm. Recent spat cohorts experience natural winter mortality (only the hardiest 6–8 month-olds survive). Any surviving adults on gear are likely in poor condition or dead ("spent").
May	**None** – Winter quiescence; no reproductive activity.	**Over-wintering stage:** juvenile oysters persist but grow little. Survivors from last spring's spatfall are now 8–9 months old, still 20–30 mm. They will become the second-year cohort come spring. Oysters of any age have low *Bonamia* loads now (parasite in latent phase)[1].
June	**None** – No larvae present.	Coldest months (~10 °C); oysters remain inactive. Juveniles on structures experience minimal growth and some natural attrition. This is a period of **low Bonamia risk** (parasite at almost undetectable prevalence in oyster population)[2].
July	**None** – No spawning (mid-winter).	Gonad development is just starting internally in larger oysters as days lengthen, but no spawning. **Growth resumes** slowly late in month as temperature begins to rise from annual minimum (~9–10 °C) (Heenan 2019). Second-year juveniles (~30 mm) prepare for rapid growth ahead.

[1] https://fs.fish.govt.nz/Doc/5541/OYU5_07.pdf.ashx
[2] ibid

August	**Low** – Onset of reproductive season. Some oysters initiate male gametogenesis by late August as SST ~11–12 °C (Heenan 2019). A few early males may spawn sperm, but **no larvae yet** (females not brooding this early).	**Rapid growth onset:** with spring warming, juveniles from last year's spat (~30 mm) put on new shell – many will reach 40–50 mm by end of spring. Some 1-year-olds attain male sexual maturity in this second summer (Michael & Shima 2018). Any remnant adult oysters on gear will begin gametogenesis now (mostly as males) (Michael & Shima 2018).
September	**Medium** – Breeding starts in earnest. Many oysters ripe as males; initial female activity begins. **First brooding of season observed** (small % of oysters incubating larvae by mid-spring) (Heenan 2019). Larval release is still limited but detectable by late Sep in favorable years.	Settlement **begins**: a trickle of spat may settle on structures in late Sep. Juvenile growth continues; 1+ year-olds (40–50 mm) may spawn as males now. A few larger individuals (>50–60 mm) could function as females and *brood larvae* at this size (Heenan 2019). (Foveaux oysters ~53 mm have been observed brooding in warm years (Heenan 2019).)
October	**High** – Spawning in full swing. Both male and female phases active; brooding rates increase. Larval output rises through Oct, with **more oysters (~5–10%) brooding** by late spring (Michael & Shima 2018, Heenan 2019). Planktonic pediveligers present; **spatfall increases**.	**Major spat settlement** on farm surfaces begins. Spat collectors in similar NZ environments show peak settlement starting in Oct (Brown *et al.* 2010). Newly settled spat (<1 mm) attach firmly and start growing. Second-year oysters (>1 yr old) now often switch to female function; some may incubate larvae if ~60 mm size (Broekhuizen *et al.* 2011).

November	**High (Peak) – Peak larval release** period. Brooding prevalence at or near annual maximum (historically, the greatest proportion of oysters incubating larvae is observed Nov–Dec) (Brown *et al.* 2010). Large pulses of larvae settle this month. Spatfall rates on collectors **highest in Nov** in many years (Brown *et al.* 2010).	**Peak spatfall**: heavy settlement on any available substrate. Spat densities can reach hundreds per m^2 on fouled surfaces (e.g. ~1700 spat/m^2 in 1999–2000 summer surveys)[3]. Spat from early spring are now visible (2–5 mm). Year-2 juveniles (50–60 mm) slow their growth as energy goes into spawning; many have become female and are brooding. These older oysters will be post-spawn (spent) by late summer, potentially carrying high *Bonamia* loads if infected.
December	**High (Peak)** – Spawning and brooding still at peak levels. A large portion of the population breeds through December (e.g. up to ~20% brooding in warmer regions) (Brown *et al.* 2010), though Foveaux percentages are likely lower (few percent). Continuous larval release sustains **high spatfall** into early summer.	**Mass settlement continues.** Newly settled oysters from spring now 5–10 mm by end of December. Older juveniles (>1 yr) reach 60–70 mm if growth conditions are good – many of these are now at first female maturity size (60 mm) (Broekhuizen *et al.* 2011) and will have completed a brooding cycle. Oyster condition declines after spawning, so any >2-year-olds on structures will enter the new year weakened and susceptible to *Bonamia* proliferation.

Annotations: **Bold** = peak periods or key stages. "Recruits" refer to legally fishable size (~58 mm shell height, ~3+ years age). Temperature ranges are seasonal averages for Foveaux Strait (winter ~9–10 °C; summer ~13–15 °C). Spatfall intensity can vary year to year with environmental factors (e.g. mild winters and warm springs can advance and amplify spawning, whereas cold summers can suppress it (Heenan 2010, Broekhuizen *et al.* 2011).

[3] Oyster plenary report: https://www.mpi.govt.nz/dmsdocument/66348/direct/

Recommended Biofouling Clearance Schedule

Objective: Prevent *O. chilensis* from accumulating on salmon farm equipment to the point where they spawn or contain high *Bonamia* loads. This requires proactive, timed cleaning that considers the oyster's life cycle. Note that nets are cleaned on a regular basis and do not represent a risk. The below relates to non-net infrastructure.

Below is a recommended schedule and rationale:

1. **Winter (Primary Annual Clearance –July):** Clear oyster fouling before water warms and spawning begins. *Rationale:* Oysters present will mostly be juveniles that settled the previous summer; by removing them at this point (when *Bonamia* levels are minimal[4]), we prevent them from maturing in spring or transmitting disease. July is before the spawning window (which starts September); this cleaning eliminates nearly all potential broodstock from the farm each year. It also removes any 2+ oysters that were previously missed as spat or 1-year olds that could be more heavily infected, at a time when disturbance is least likely to spread *Bonamia* (cold water, parasite latent).
2. **"Hot-spot" Cleaning:** Monitor and more frequently clean high-risk areas of infrastructure. These include deep structures (nets/pontoons near the seafloor) and low-flow or shaded zones (interior of pen nets, leeward sides of ropes, underside of floats) where oyster spat may concentrate. Cleaning in March/April may be triggered by heavy spat fall or pockets of 20-30mm oysters being located.

Factors to be aware of to inform any subsequent adaptation of the biofouling management program include:

- Avoid major cleaning during January/February unless absolutely necessary, i.e. unless it coincides with a farm level fallow period when cleaning to manage *P. salmonis* risk is indicated. During this late summer period, any older oysters on the farm may be carrying higher *Bonamia* loads. Disturbing them can release a pulse of pathogens into the environment. If removal is needed in this window do not use water blasting or destructive methods, but try to remove those over 35mm intact (to prevent them gaping and releasing parasites in situ).
- If there is heavy spat fall noted, or the primary annual clearance is becoming difficult due to oyster numbers, then a spat clean in early Autumn (March/April) immediately after the summer breeding season ends may become beneficial. *Rationale:* This will remove the new cohort of spat that settled during spring/summer *before* they overwinter and grow larger. By March, those spat are 5–25 mm and not yet sexually mature nor significantly infected, so removing them is easier and poses low disease risk. It prevents these juveniles from

[4]Oyster plenary report: https://fs.fish.govt.nz/Doc/5541/OYU5_07.pdf.ashx

surviving into the next spring (when they would be one year old and ready to spawn as males).

Inherent risk mitigation in the proposal:

- The farming structures will be placed over sandy sediment, with some shell debris in places, representative of a mobile seabed and higher energy environment. These areas tend to be depauperate of oysters (Cranfield 2004), and areas with current velocity in excess of 0.25 m/sec and seabed motion of >0.8 cm/day are noted to be inconsistent with flat oyster survival (Kammermans *et al.* 2018). Anchors, chains and anchor blocks will be located in the area of maximum benthic (coarse sand) movement and are expected to be regularly scoured by water column energy and thus are unlikely to become fouled to any significant degree. Warps, chains and subsurface fouled structures being cleaned could result in drop off of biofouling, and in the case of bivalves we must consider the viability of these. Given that farms will be located above high energy, primarily sandy benthos the survival potential of these organisms is minimal.
- With cleaning programmed to remove small oysters (< 1+ size) they are likely also to be either destroyed during the removal process or predated rapidly on the benthos. Any larger bivalves are likely to become buried in the benthos rapidly. Any residual risk from surviving oysters and bivalves can be addressed by monitoring of seabed populations as part of the proposed benthic monitoring programme, with remedial action potentially undertaken in the form of dredging to reduce population densities. Given the energy and makeup of the benthos, capture of the flat oyster debris is not considered necessary, noting also that biofouling waste capture is not undertaken on marine farms elsewhere in New Zealand, or globally in an effective manner, due to unavailability of effective and affordable methods.
- Grower nets and any predator nets will be net cleaned on a regular basis and thus the nets will not be a source of bivalve fouling.

In addition to programmed cleaning, residual flat oyster biofouling risk may also be managed as follows:

1. Where applicable or possible, the farm may be constructed using materials resistant to fouling;
2. In the initial development period of the farm, a sample of any settled oysters may be screened by molecular diagnostic methods, for the presence of Bonamia spp. to inform ongoing development of the biofouling management program.

References for Appendix 1 Risk Assessment

Altinok I (2004). The infectious route of *Yersinia ruckeri* is affected by salinity. *Bulletin of the European Association of Fish Pathologists* 24: 253-259.

Anderson C (1996) Distribution of salmonid diseases in New Zealand. Surveillance 23: 23–24

Anderson CD (1995). Surveillance for fish diseases. Surveillance 22(4): 13

Anderson CD (1998). Survey of New Zealand Salmonids for OIE List B viruses. Surveillance 25(4): 9-10.

Anderson CD, Knowles G, de Lisle G (1994). A survey for *Yersinia ruckeri* and *Aeromonas salmonicida* in farmed and wild fish. *Surveillance* 2(3): 39-40.

Arkush KD, Edes HL, McBride AM, Adkison MA, Hedrick RP (2006) Persistence of *Piscirickettsia salmonis* and detection of serum antibodies to the bacterium in white seabass *Atractoscion nobilis* following experimental exposure. Dis Aquat Org 73:131-139

Arzul, I., Carnegie, R. B., Chollet, B., Robert, M., Francois, C., Joly, J. P. & Morga, B. (2009). Effects of temperature and salinity on the survival of Bonamia ostreae, a parasite of the flat oyster Ostrea edulis. *Diseases of Aquatic Organisms, 85(1), 67–75.*

Austin B, Austin DA (2007). Bacterial fish pathogens: disease in farmed and wild fish. *4th edition*. Springer. *552 pp.*

Barnes, A. C., Delamare-Deboutteville, J., Gudkovs, N., Brosnahan, C., Morrison, R., Carson, J. (2016) Whole genome analysis of Yersinia ruckeri isolated over 27 years in Australia and New Zealand reveals geographical endemism over multiple lineages and recent evolution under host selection. *Microbial genomics, 30;2(11)*

Berthe, F. C. J., & Hine, P. M. (2003). Bonamia exitiosa Hine, Cochennec, and Berthe, 2001 is proposed instead of Bonamia exitiosus. *Journal of Invertebrate Pathology, 83(3), 288*.

Birkbeck HT, Rennie S, Hunter D, Laidler A, Wadsworth S (2004). Infectivity of a Scottish isolate of Piscirickettsia salmonis for Atlantic salmon Salmo salar and immune response of salmon to this agent. *Diseases of Aquatic Organisms 60: 97-103.*

Bishop, M. J., Mayer-Pinto, M., & Airoldi, L. (2006). Biofouling as a vector for the transfer of marine organisms and pathogens. Marine Pollution Bulletin, 52(7), 805–810.

Boustead NC (1989). A guide to diseases of salmon in New Zealand. *New Zealand Fisheries Report No. 112, MAFFish, Christchurch. 88pp*

Boustead, N. C. (1993). Detection and New Zealand distribution of Myxobolus cerebralis, the cause of whirling disease of salmonids. *New Zealand Journal of Marine and Freshwater Research, 27, 431-436.*

Bovo G, Hill B, Husby A, Hastein T, Michel C, Olesen NJ, Storset A and Midtlyng P (2005). *Work package 3 report: Pathogen survival outside the host, and susceptibility to disinfection*. VESO, P. O. Box 8109 Dep., N-0032 Oslo, Norway.

Boxaspen, K. (2006). A review of the biology and genetics of sea lice. *ICES Journal of Marine Science, 63(7), 1304–1316.*

Broekhuizen, N., Lundquist, C.J., Hadfield, M.G., & Brown, S.N. (2011) Dispersal of Oyster (Ostrea chilensis) Larvae in Tasman Bay Inferred using a Verified Particle Tracking Model that Incorporates Larval Behavior. *Journal of Shellfish Research 30(3), 643-658*

Brosnahan CL, Georgiades E, McDonald C, Keeling SE, Munday JS, Jones B. (2019a). Optimisation and validation of a PCR to detect viable *Tenacibaculum maritimum* in salmon skin tissue samples. *Journal of Microbiological Methods. 159:186–193.*

Brosnahan, C. L., Ha, H. J., Booth, K., Mcfadden, A., & Jones, J. B. (2017a). *First report of a rickettsia-like organism from farmed Chinook salmon, Oncorhynchus tshawytscha (Walbaum), in New Zealand. New Zealand Journal of Marine and Freshwater Research, 51, 356 - 369.*

Brosnahan CL, Munday JS, Ha HJ, Jones JB (2018). New Zealand rickettsia-like organism (NZ-RLO) and *Tenacibaculum maritimum*: Distribution and phylogeny in farmed Chinook salmon (*Oncorhynchus tshawytscha*). *Journal of Fish Diseases.* 42(1), 85-95

Brosnahan CL, Munday JS, Ha HJ, Preece M, Jones JB. (2018). New Zealand rickettsia-like organism (NZ-RLO) and *Tenacibaculum maritimum:* Distribution and phylogeny in farmed Chinook salmon (*Oncorhynchus tshawytscha*). *Journal of Fish Diseases. 42:85–95*

Brosnahan, C. L., Munday, J. S., Davie, P. S., Kennedy, L., Preece, M. A., Barnes, S., Jones, J. B., & McDonald, W. (2019b). Pathogenicity of the bacterium New Zealand rickettsia-like organism (NZ-RLO2) in Chinook salmon Oncorhynchus tshawytscha smolt. *Diseases of aquatic organisms, 134 3, 175-187.*

Brosnahan, C., Humphrey, S., Knowles, G., Ha, H. J., Pande, A., & Jones, J. J. (2017b). Nocardiosis in freshwater reared Chinook salmon (Oncorhynchus tshawytscha). *New Zealand Veterinary Journal, 65, 214 - 218.*

Brown, S., Handley, S., Michael, K. and Schiel, D.(2010) 'Annual pattern of brooding and settlement in a population of the flat oyster Ostrea chilensis from central New Zealand', *New Zealand Journal of Marine and Freshwater Research, 44: 4, 217 — 227*

Buller NB (2014) Bacteria and fungi from fish and other aquatic animals: a practical identification manual, 2nd Edition. CAB International, Oxfordshire, UK. *881pp*

Bulleri, F., & Airoldi, L. (2005). Artificial marine structures facilitate the spread of a non-indigenous green alga, Codium fragile ssp. tomentosoides, in the north Adriatic Sea. *Journal of Applied Ecology, 42(6), 1063–1072.*

Carbines G, Cole RG (2009) Using a remote drift underwater video (DUV) to examine dredge impacts on demersal fishes and benthic habitat complexity in Foveaux Strait, Southern New Zealand. *Fisheries Research 96, 230-237*

Carson J, Wilson T (2009). Yersinosis in fish. Australian and New Zealand Standard Diagnostic Procedure. https://www.agriculture.gov.au/sites/default/files/documents/anzsdp-yersiniosis_0.pdf, accessed 12/08/2025.

Cole K M, Supan J, Ramirez A and Johnson C N (2015) Suspension of oysters reduces the populations of Vibrio parahaemolyticus and Vibrio vulnificus. Letters in Applied Microbiology; 61: 209-213

Corbeil S, Morrison R, Crane MS (2019). SCAHLS Australian and New Zealand Standard Diagnostic Procedures (ANZSDP) for Piscirickettsia salmonis and piscine rickettsia-like organisms.. Accessed 10/08/2025

Costello, M. J. (2006). Ecology of sea lice parasitic on farmed and wild fish. Trends in Parasitology, 22(10), 475–483.

Costello, K.E., Lynch, S.A., McAllen, R., O'Riordan, R. M., Culloty, S. C. (2021) The role of invasive tunicates as reservoirs of molluscan pathogens. *Biol Invasions* **23**, 641–655

Cranfield, H. J., Dunn, A., Doonan, I. J., Michael, K. P., & Stotter, D. R. (1999). Bonamia infection in the New Zealand dredge oyster (Tiostrea chilensis) in Foveaux Strait: Management implications. *New Zealand Journal of Marine and Freshwater Research, 33(2), 305–313.*

Cranfield H. J., Dunn, A., Doonan, I. J., Michael, K. P., (2005) *Bonamia exitiosa* epizootic in *Ostrea chilensis* from Foveaux Strait, southern New Zealand between 1986 and 1992*, ICES Journal of Marine Science,* 62(1)*,* 3–13

Cranfield, H. J., Michael, K. P., & Doonan, I. J. (2003). The effects of fishing on the benthic community structure of Foveaux Strait oysters. *New Zealand Journal of Marine and Freshwater Research, 37(1), 39–52.*

Cranfield, H. J., Michael, K. P., Doonan, I. J., & Dunn, A. (2004). *Sea bed habitats of the eastern Tasman Bay, New Zealand*. New Zealand Fisheries Assessment Report 2004/22. Ministry of Fisheries, Wellington.

Cranfield, H. J., Michael, K. P., Doonan, I. J., & Stotter, D. R. (2005). Foveaux Strait dredge oyster (Tiostrea chilensis) fishery and bonamia disease management. *New Zealand Journal of Marine and Freshwater Research, 39(4), 695–711.*

Culloty SC & Mulcahy MF (2007) Bonamia ostreae in the native oyster Ostrea edulis. A Review. Marine Environment and Health Series No. *29, Marine Institute.*

Cvitanich, J. D., Garate, O., Smith, C. E. (1991) The isolation of a rickettsia-like organism causing disease and mortality in Chilean salmonids and its confirmation by Koch's postulate. *Journal of Fish Diseases, 14, 121–145.*

DAFF (2013). Disease strategy: Piscirickettsiosis (Version 1). In: Australian Aquatic Veterinary Emergency Plan (AQUAVETPLAN), Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, ACT.

Davey, N. K.; Hartill, B. (2011). Survey of the Southland recreational blue cod fishery during the 2009–2010 fishing year. *New Zealand Fisheries Assessment Report 2011/57*. Ministry of Fisheries.

Davies KR, McColl KA, Wang LF, Yu M, Williams LM, Crane MSJ (2010) Molecular characterisation of Australasian isolates of aquatic birnaviruses. Dis Aquat Org 93:1-15

Dempster T, Uglem I, Sanchez-Jerez P, Fernandez-Jover D, Bayle-Sempere J, Nilsen R, Bjørn PA (2009). Coastal salmon farms attract large and persistent aggregations of wild fish: an ecosystem effect. Marine Ecology Progress Series 384: 1-14.

Deveney, M. R., Bayly, T., & Svane, I. (2017). Biofouling as a vector for the translocation of marine organisms: Risks and management. Aquatic Invasions, 12(4), 443–456.

Diggles BK, Carson J, Hine PM, Tait M (2000). Vibrio species associated with mortalities in hatchery reared turbot (Colistium nudipinnis) and brill (C. guntheri) in New Zealand. *Aquaculture 183: 1-12*.

Diggles BK, Hine PM, Handley S, Boustead NC. (2002). *A handbook of diseases of importance to aquaculture in New Zealand*. Wellington: NIWA. p. *200*

Diggles, B. K., & Hine, P. M. (2002). Bonamia exitiosa in Ostrea chilensis: Experimental transmission and description. *New Zealand Journal of Marine and Freshwater Research, 36(3), 645–656.*

Dinamani, P., Hine, P. M., & Jones, J. B. (1987). Occurrence and significance of Bonamia sp. in the New Zealand dredge oyster Tiostrea lutaria. *Diseases of Aquatic Organisms, 3(1), 37–44.*

Doonan, I. J., Cranfield, H. J., & Michael, K. P. (1999). Catastrophic reduction of the oyster, Tiostrea chilensis, in Foveaux Strait, New Zealand, due to infection with Bonamia sp. *New Zealand Journal of Marine and Freshwater Research, 33(3), 497–508.*

Douglas-Helders GM, Dawson DR, Carson J, Nowak BF (2002). Wild fish are not a significant reservoir for Neoparamoeba pemaquidensis (Page, 1987). *Journal of Fish Diseases 25: 569–574.*

Elston, R. A., Farley, C. A., & Kent, M. L. (1986). Occurrence and significance of bonamiasis in European flat oysters Ostrea edulis in North America. *Diseases of Aquatic Organisms, 2(1), 49–54.*

Engelsma, M. Y., Culloty, S. C., Lynch, S. A., Arzul, I., & Carnegie, R. B. (2014). Bonamia parasites: A review of recent developments. *Diseases of Aquatic Organisms, 110(1–2), 5–23.*

Evensen Ø. (2016). Immunization Strategies against Piscirickettsia salmonis Infections: Review of Vaccination Approaches and Modalities and Their Associated Immune Response Profiles. Frontiers in immunology, 7, 482

Ferguson HW, Delannoy CM, Hay S, Nicolson J, Sutherland D, Crumlish M (2010). Jellyfish as vectors of bacterial disease for farmed salmon (Salmo salar). *Journal of Veterinary Diagnostic Investigation 22: 376–382*

Ford, S. E., & Tripp, M. R. (2009). Diseases and parasites of oysters. In R. E. Shumway (Ed.), Oyster Biology and Culture (pp. *253–287)*. Elsevier.

Fryer JL, Hedrick RP (2003) Piscirickettsia salmonis: a Gram-negative intracellular bacterial pathogen of fish. *Journal of Fish Diseases 26(5), 251-262*

Fryer JL, Lannan CN (1994). Rickettsial and chlamydial infections of freshwater and marine fishes, bivalves, and crustaceans. Zoological Studies 33: 95·107.

Fu, D., Dunn, A., Michael, K. P., & Hills, J. (2016). The development and performance of a length-based stock assessment of Foveaux Strait oysters (Ostrea chilensis, OYU 5) in southern New Zealand, and application to management. *Fisheries Research(183), 506-517*.

Gias E, Brosnahan CL, Orr D, Binney B, Ha HJ, Preece MA, Jones B (2018) In vivo growth and genomic characterisation of rickettsia-like organisms isolated from farmed Chinook salmon (Oncorhynchus tshawytscha) in New Zealand. J Fish Dis 41: 1235−1245

Grimnes, A., & Jakobsen, P. J. (1996). The physiological effects of salmon lice infection on post-smolt of Atlantic salmon. *Journal of Fish Biology, 48(6), 1179–1194*.

Hamre, L. A., Bui, S., Oppedal, F., Skern-Mauritzen, R., Dalvin, S., & Nilsen, F. (2013). Development of the salmon louse Lepeophtheirus salmonis parasitic stages in relation to temperature and salinity. *Aquaculture, 416–417, 242–250*.

Heenan S (2019) Aspects of Reproduction in a Post-Bonamia exitiosa Epidemic Ostrea chilensis Fishery, Foveaux Strait, Southern New Zealand. *MSc Thesis, University of Otago, Dunedin*.

Hervio D, Bachere E, Boulo V, Cochennec N, Vuillemin V, LeCoguic Y, Cailletaux G, Mazurie J, Mialhe E (1995). Establishment of an experimental infection protocol for the flat oyster, *Ostrea edulis*, with the intrahaemocytic protozoan parasite, *Bonamia ostreae*: application in the selection of parasite- resistant oyster. *Aquaculture* 132: 183-194.

Hewitt GC (1963). Some New Zealand parasitic copepoda of the family Caligidae. Transactions of the Royal Society of New Zealand 4: 61-115.

Hewitt, G. C., & Hine, P. M. (1972) Checklist of parasites of New Zealand fishes and of their hosts, *New Zealand Journal of Marine and Freshwater Research,* 6:1-2, 69-114

Hewitt GC, Little RW (1972). Whirling disease in New Zealand trout caused by *Myxosoma cerebralis* (Hofer, 1903) (Protozoa: Myxosporidia). *New Zealand Journal of Marine and Freshwater Research* 6: 1-10.

Hill, K. M., Carnegie, R. B., & Burreson, E. M. (2014). Phylogenetics and global distribution of Bonamia parasites. *International Journal for Parasitology: Parasites and Wildlife, 3(1), 34–50*.

Hine PM (1996). The ecology of Bonamia and decline of bivalve molluscs. *New Zealand Journal of Ecology 20: 109-116*

Hine PM (1997). Health status of commercially important molluscs in New Zealand. Surveillance 24: 25-28.

Hine PM (2002a) Severe apicomplexan infection in the oyster Ostrea chilensis: a possible predisposing factor in bonamiosis. Dis Aquat Org 51:49-60

Hine PM (2002b). Results of a survey on shellfish health in New Zealand in 2000. Surveillance

Hine PM, Jones JB & Diggles BK (2000) A checklist of parasites of New Zealand fishes, including previously unpublished records. *NIWA Technical Report 75, NIWA, Wellington, New Zealand, 95pp*

Hine PM, Jones JB (1994). Bonamia and other aquatic parasites of importance to New Zealand. *New Zealand Journal of Zoology 21: 49-56.*

Hine PM, Wesney B, Besant P (1998). Replication of a herpes-like virus in larvae of the flat oyster Tiostrea chilensis at ambient temperatures. *Diseases of Aquatic Organisms 32:161-171.*

Hine, P. M. (1991a). The annual pattern of infection by Bonamia sp. in New Zealand flat oysters, Tiostrea chilensis. *Aquaculture, 93(3), 241–251.*

Hine, P. M. (1991b). Ultrastructural observations on Bonamia sp. in New Zealand flat oysters. *Aquaculture, 93(3), 251–261.*

Hine, P. M. (1996). The ecology of Bonamia and the epidemiology of bonamiosis in New Zealand. *New Zealand Journal of Marine and Freshwater Research, 30(4), 609–622.*

Hine, P. M. & Diggles, B. K. (2002) Prokaryote infections in the New Zealand scallops *Pecten novaezelandiae* and *Chlamys deliculata*. *Diseases of Aquatic Organisms,* 50: 137-144

Hine, P. M., & Jones, J. B. (1994). Bonamia and other aquatic parasites of importance in Australasia. In A. D. McDonald & A. M. Thomson (Eds.), Parasitic Diseases of Fish and Shellfish (pp. *53–60)*. CAB International.

Hine, P. M., Cochennec, N., & Berthe, F. C. J. (2001). Bonamia exitiosa n. sp. (Haplosporidia) infecting flat oysters Ostrea chilensis in New Zealand. *Diseases of Aquatic Organisms, 47(1), 63–72.*

Hine PM, Diggles BK, Parsons MJD, Pringles A, Bull B (2002). The effects of stressors on the dynamics of *Bonamia exitiosa* Hine, Cochennec-Laureau & Berthe, infections in flat oysters *Ostrea chilensis* (Philippi). *Journal of Fish Diseases* 25: 545-554.

House ML, Bartholomew JL, Winton JR, Fryer L (1999). Relative virulence of three isolates of Piscirickettsia salmonis for coho salmon, Oncorhynchus kisutch. *Diseases of Aquatic Organisms 35: 107–113.*

Howard, D. W. (1994). The possibility of bonamiasis transmission through hull fouling. *Journal of Shellfish Research, 13(1), 193.*

Howell MJ (1967). The trematode Bucephalus longicornutus (Manter 1954) in the New Zealand mud oyster, Ostrea lutaria. Transactions of the Royal Society of New Zealand. Zoology. *8: 221-237.*

Jones JB (1981). A new Microsporidium from the oyster Ostrea lurida in New Zealand. *Journal of Invertebrate Pathology 38: 67-70.*

Jones JB (1988). New Zealand parasitic Copepoda; genus Caligus Muller, 1785 (Siphonostomatoida: Caligidae). *New Zealand Journal of Zoology 15: 397-413.*

Jones SR, Prosperi-Porta G, Kim E, Callow P, Hargreaves NB (2006a). The occurrence of *Lepeophtheirus salmonis* and *Caligus clemensi* (Copepoda: Caligidae) on three-spine stickleback *Gasterosteus aculeatus* in coastal British Columbia. *Journal of Parasitology* 92: 473–480.

Jones SR, Kim E, Dawe S (2006b). Experimental infections with *Lepeophtheirus salmonis* (Krøyer) on threespine sticklebacks, *Gasterosteus aculeatus* L. and juvenile Pacific salmon, *Oncorhynchus* spp. *Journal of Fish Diseases* 29: 489–495.

Kabata, Z. (1984). Diseases caused by metazoans: Crustaceans. In O. Kinne (Ed.), Diseases of Marine Animals, Volume IV, Part 1 (pp. *321–399)*. Hamburg: Biologische Anstalt Helgoland.

Kammermans P, Walles B, Kraan M, Van Duren LA, Kleisen F, Van der Have TM, Smaal AC, poelman M (2018) Offshore wind farms as potential locations for flat oyster (Ostrea edulis) restoration in the Dutch North sea. Sustainability 10(11), 3942-3965.

Key JM (2001) Growth and condition of the Greenshell mussel Perna canaliculus, in Big Glory Bay, Stewart Island: Relationships with environmental parameters. *MSc thesis, University of Otago, 2001.*

Krkošek, M., Lewis, M. A., Morton, A., Frazer, L. N., & Volpe, J. P. (2007). Epizootics of wild fish induced by farm fish. *Proceedings of the National Academy of Sciences, 104(42), 16223–16228.*

Laing, I., Dunn, P., & Peeler, E. (2014). Bonamia and its impact on oyster culture in Europe. *Journal of Invertebrate Pathology, 118(1), 2–9.*

Lama, A., & Montes, J. (1993). Influence of depth of culture on infection of the European flat oyster (Ostrea edulis) by Bonamia ostreae. Bulletin of the European Association of Fish Pathologists, 13(1), 17–20.

Lane HS (2018). Studies on Bonamia parasites (Haplosporidia) in the New Zealand flat oyster Ostrea chilensis. *A thesis submitted for the degree of Doctor of Philosophy, University of Otago, New Zealand, April 2018. 148 pp.*.

Lane HS, Webb SC, Duncan J (2016) Bonamia ostreae in the New Zealand oyster Ostrea chilensis: a new host and geographic record for this haplosporidian parasite. Dis Aquat Org 118:55-63

Lane HS, Jones JB, Poulin R (2018). Comparative population genetic study of an important marine parasite from New Zealand flat oysters. *Marine Biology* 165: 9.

Lane, H. S., Webb, S. C., & Cranfield, H. J. (2016). *First report of Bonamia ostreae in the southern hemisphere*. *Diseases of Aquatic Organisms, 118(1), 71–78.*

Lannan CN, Fryer JL (2006) Extracellular survival of Piscirickettsiosis salmonis. *Journal of Fish Diseases, 17(5), 545-548*

Larenas JJ, Bartholomew J, Troncoso O, Ledezma H, Fernandez S, Sandoval N, Vera P, Contreras J and Smith P A (2003). Experimental vertical transmission of Piscirickettsia salmonis and in vitro study of the attachment and mode of entrance into the ovum. *Diseases of Aquatic Organisms, 56, 25-30.*

Levipan, H. A., Irgang, R., Yáñez, A., Avendano-Herrera R (2020) Improved understanding of biofilm development by Piscirickettsia salmonis reveals potential risks for the persistence and dissemination of piscirickettsiosis. Sci Rep 10, 12224

Lynch, S. A., Armitage, D. V., Wylde, S., Mulcahy, M. F., Culloty, S. C. (2005) The susceptibiliy of young prespawning oysters, *Ostrea* edulis, to *Bonamia* ostreae. *Journal of Shellfish Research* 24(4), 1019-1025

MacKenzie, K., Longshaw, M., Begg, G. S., & McVicar, A. H. (1998). Sea lice (Caligus elongatus) on wild sea trout (Salmo trutta) in Scotland. *ICES Journal of Marine Science, 55(2), 151–162.*

Mardones F (2025) Presentation at SRS Initiative meeting, Galway, Ireland, April 23-25

Martinsen KH, Thorisdottir A, Lillehammer M (2018). Effect of hydrogen peroxide as treatment for amoebic gill disease in Atlantic salmon (Salmo salar L.) in different temperatures. *Aquaculture Research 49: 1733–1739*

Mauel MJ, Miller DL (2002). Piscirickettsiosis and piskirickettsiosis-like infections in fish: a review. Veterinary Microbiology 87: 279-289.

Mauel MJ, Miller DL, Frazier K, Liggett AD, Styer L, Montgomery-Brock D, Brock J (2003). Characterization of a piscirickettsiosis-like disease in Hawaiian tilapia. *Diseases of Aquatic Organisms 53: 249-255*.

McAllister P, Beba, J & Wagner B. (2000). Susceptibility of Arctic Char to Experimental Challenge with Infectious Hematopoietic Necrosis Virus (IHNV) and Infectious Pancreatic Necrosis Virus (IPNV). *Journal of Aquatic Animal Health. 12, 35-43*

McAllister, P. E., Owens, W. J. (1992). Infectious pancreatic necrosis virus in the environment: relationship to effluent from fish hatcheries. *Journal of Aquatic Animal Health, 4(4), 298–303*

McIntyre L, Rawdon T, Johnston C (2010). Animal health surveillance. Salmonid surveillance during 2009. Surveillance 37(2): 16-19.

Michael K (2007) Summary of information in support of the Foveaux Strait Oyster Fishery Plan: The Foveaux Strait ecosystem and effects of oyster dredging. *Final Research Report for Ministry of Fisheries Research Project ZBD200504, objectives 1–5*

Michael KP (2019) Recruitment of Ostrea chilensis (Philippi, 1844) in Foveaux Strait, Southern New Zealand, PhD Thesis, Victoria University of Wellington 2019.

Michael KP, Shima JS (2018) Four-year decline in Ostrea chilensis recruits per spawner in Foveaux Strait, New Zealand, suggests a diminishing stock−recruitment relationship. Marine Ecology Progress Series: 600, 85-98

Michael, K. P., Cranfield, H. J., & Doonan, I. J. (2015). Bonamia exitiosa and its impact on New Zealand's oyster fisheries. *New Zealand Fisheries Assessment Report 2015/38*. Ministry for Primary Industries.

Michael, K. P., Cranfield, H. J., & Doonan, I. J. (2017). Updated stock assessment for Foveaux Strait oysters. *New Zealand Fisheries Assessment Report 2017/44*. Ministry for Primary Industries.

Ministry for Primary Industries. (2017a). Bonamia ostreae response update – May 2017. Ministry for Primary Industries, Wellington, New Zealand.

Ministry for Primary Industries. (2017b). Controlled Area Notice for Bonamia ostreae. Ministry for Primary Industries, Wellington, New Zealand.

Ministry for Primary Industries. (2018). Bonamia ostreae response update – 2018. Ministry for Primary Industries, Wellington, New Zealand.

Mitchell SO, Rodger HD (2011). A review of infectious gill disease in marine salmonid fish. *Journal of Fish Diseases 34: 411-432.*

MPI (2016). Legal controls to manage the spread of an unwanted organism in Marlborough farmed salmon.. Accessed 10/08/2025

Munday BL, Zilberg D, Findlay V (2001). Gill disease of marine fish caused by infection with Neoparamoeba pemaquidensis. *Journal of Fish Diseases 24, 497–507.*

Murray AG, Wardeh M, McIntyre KM (2016). *Using the H-index to assess disease priorities for salmon aquaculture*. Preventive Veterinary Medicine 126: 199–207

Mutoloki, S., Jarp, J., Evensen, Ø. (2006). Infectious dose and shedding of Infectious Pancreatic Necrosis Virus in Atlantic salmon post-smolts. *Journal of Fish Diseases, 29(3), 177–186.*

NIWA. (2017). Surveillance for Bonamia ostreae in Foveaux Strait oysters. *National Institute of Water and Atmospheric Research, Wellington, New Zealand.*

Olivares, J. & Marshall, S.H. (2010) Determination of minimal concentration of *Piscirickettsia salmonis* in water columns to establish a fallowing period in salmon farms. *Journal of Fish Diseases*, 33(3), 261-266

Pike, A. W., & Wadsworth, S. L. (1999). Sealice on salmonids: Their biology and control. *Advances in Parasitology*, 44, 233–337.

Price D, Ibarra R, Sanchez J, St-Hilaire S (2017) A retrospective assessment of the effect of fallowing on piscirickettsiosis in Chile. *Aquaculture: 473, 400-406.*

Ranier S (1973). Polydora and related genera (polychaeta: spionidae) from Otago waters. *Journal of the Royal Society of New Zealand 3: 545-564.*

Read GB (2010). Comparison and history of Polydora websteri and P. haswelli (Polychaeta: Spionidae) as mud-blister worms in New Zealand shellfish. *New Zealand Journal of Marine and Freshwater Research 44: 83-100.*

Reece KS, Siddall ME, Stokes NA, Burreson EM (2004). Molecular phylogeny of the Haplosporidia based on two independent gene sequences. *Journal of Parasitology* 90: 1111−1122.

Rees EE, Ibarra R, Medina M, Sanchez J, Jakob E, Vanderstichel R, St-Hilaire S (2014). Transmission of Piscirickettsia salmonis among salt water salmonid farms in Chile. *Aquaculture 428–429: 189–194.*

Reno PW (1999). Infectious pancreatic necrosis and associated aquatic birnaviruses. In: Woo PTK, Bruno DW (eds.) Fish Diseases and Disorders, Volume 3: Viral, Bacterial and Fungal Infections, pp. *1-55.*

Rozas M, Enríquez R. (2014) Piscirickettsiosis and Piscirickettsia salmonis in fish: a review. J Fish Dis.;37(3):163-88.

Santoro D (2024) The likelihood, speed, and impact of Bonamia ostreae spread from Big Glory Bay to Foveaux Strait. Biosecurity New Zealand Technical Paper No: 2024/05. Ministry for Primary Industries, Wellington, NZ. *14pp*

Scott, D. (1964) The migratory trout (Salmo trutta L.) in New Zealand. *1—The introduction of stocks*. Transcripts of the Royal Society of New Zealand Zoology, 4 (17), 209-228.

Shafiee, N. S., Mazlan, N., Abd Rahman, N. N., Shapawi, R., Shah, M. D. (2024). *Vibriosis in Aquaculture: Pathogenic Vibrio Species, Affected Animals, Diagnosis and Adverse Effects*. In: Faudzi, N. M., Shah, M. D., Mazlan, N., Raehanah Muhamad Shaleh, S. *(eds) Essentials of Aquaculture Practices*. Springer, Singapore.

Sparboe O, Koren C, Hastein T, Poppe T, Stenwig H (1986). The first isolation of Yersinia ruckeri from farmed Norwegian salmon. Bulletin of the European Association of Fish Pathologists 6: 41-42

Suong, N. T., Banks, J. C,. Fidler, A., Jeffs, A., Wakeman, K. C. & Webb, S. (2018) PCR and histology identify new bivalve hosts of Apicomplexan-X (APX), a common parasite of the New Zealand flat oyster Ostrea chilensis. *Diseases of Aquatic Organisms, (181–189).*

Suong NT, Webb S, Banks J, Wakeman KC, Lane H, Jeffs A, Brosnahan C, Jones B, Fidler A (2017). Partial 18S rRNA sequences of apicomplexan parasite 'X' (APX), associated with flat oysters Ostrea chilensis in New Zealand. *Diseases of Aquatic Organisms 127: 1-9.*

Taksdal, T., Stangeland, K., & Dannevig, B. H. (1997). Induction of infectious pancreatic necrosis (IPN) in Atlantic salmon (Salmo salar L.) and brook trout (Salvelinus fontinalis) by bath challenge of fry with infectious pancreatic necrosis virus (IPNV) serotype Sp. *Diseases of Aquatic Organisms, 28, 39–44*

Thomas MV, Faisal M (2009). *Piscirickettsia* infection in the muskellunge population of Lake St. Clair. Michigan Department of Natural Resources, Fisheries Research Report 2092, Ann Arbor, Michigan.

Thorsen BK, Enger O, Norland S, Hoff K A (1992). Long-Term Starvation Survival of Yersinia ruckeri at Different Salinities Studied by Microscopical and Flow Cytometric Methods. *Applied and Environmental Microbiology* 58: 1624-1628

Tigé, G., Grizel, H., Rabouin, M. A., Cochennec, N., Audic, G., & Langlade, A. (1984). Évolution de la situation épizootiologique en Bretagne en 1983 suite au développement de Bonamia ostreae. ICES Council Meeting Papers, CM 1984/F:14, 14 pp.

Tisdall, D. J., & Phipps, J. C. (1987). Isolation and characterisation of a marine birnavirus from returning Quinnat salmon (Oncorhynchus tshawtscha) in the South Island of New Zealand. *New Zealand veterinary journal, 35 12, 217-8.*

Treasurer, J. W., & Bravo, S. (2011). *Sea lice as a constraint to salmonid aquaculture*. In S. C. Jones & R. Beamish (Eds.), Salmon Lice: An Integrated Approach to Understanding Parasite Abundance and Distribution (pp. *80–102)*. Wiley-Blackwell.

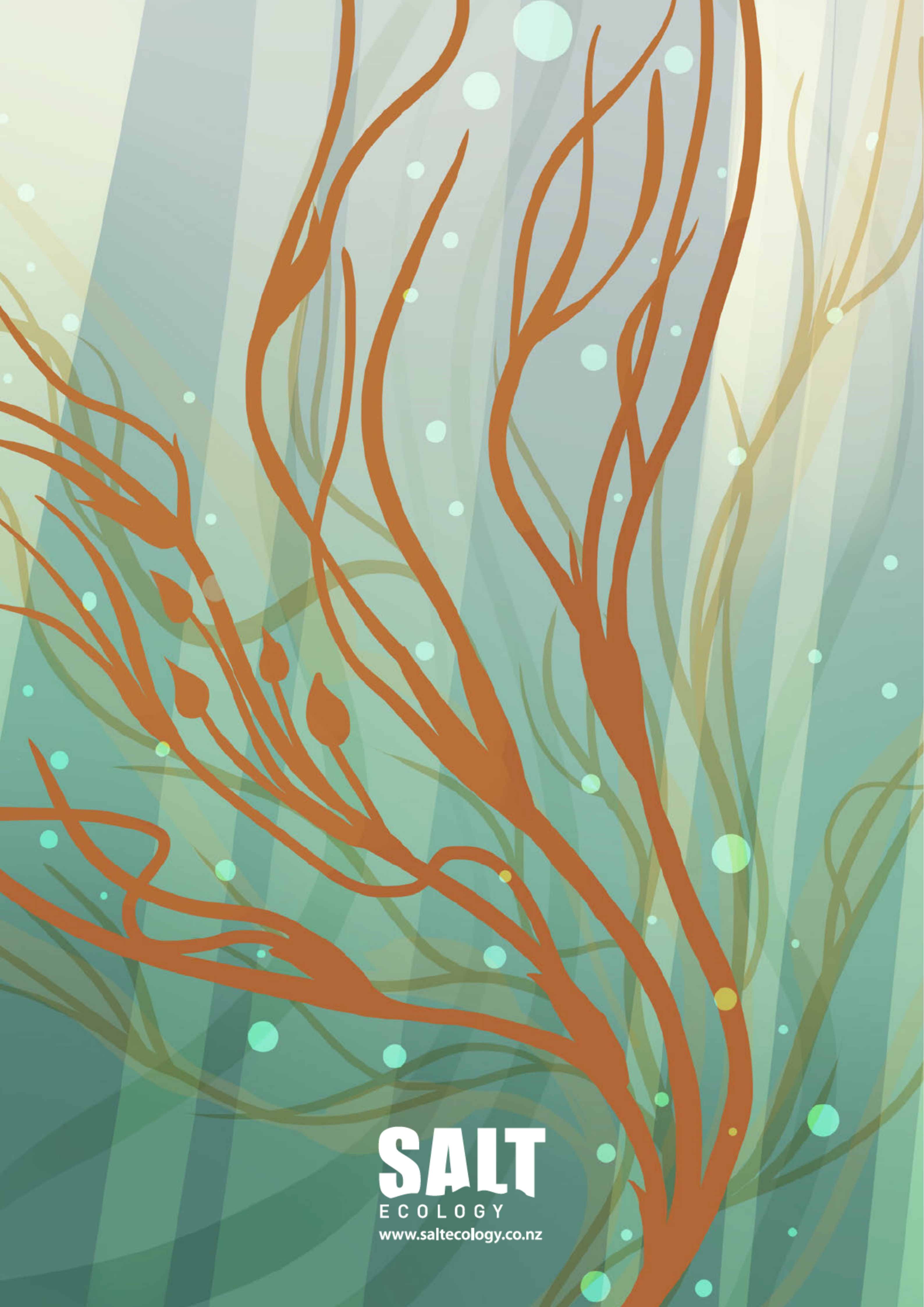
Tubbs L, Lee P, Diggles B, Jones JB, Sheppard M, Sim-Smith C, Gosai A (2006) A Review of Aquatic Diseases of Significance to New Zealand. Biosecurity New Zealand Technical Paper, NIWA, Wellington. *459pp*

Tubbs, L., Wybourne, B., & Lumsden, J. H. (2010). Nodular gill disease causing proliferative branchitis and mortality in Chinook salmon (Oncorhynchus tshawytscha). *New Zealand Veterinary Journal, 58, 59 - 61.*

Wallace IS, Gregory A, Murray AG, Munro ES, Raynard RS (2008). Distribution of infectious pancreatic necrosis virus in wild marine fish from Scottish waters with respect to clinically infected aquaculture sites producing Atlantic salmon, Salmo salar L.. *Journal of Fish Diseases 31:177-86.*

Wards, B. J., Patel, H. H., Anderson, C. D., & Lisle, G. W. (1991). Characterisation by restriction endonuclease analysis and plasmid profiling of Vibrio ordalii strains from salmon (oncorhynchus tshawytscha and oncorhynchus nerka) with vibriosis in new zealand. *New Zealand Journal of Marine and Freshwater Research, 25, 345-350.*

Wolf, K., Snieszko, S. F., Dunbar, C. E., Pyle, E. (1960). Virus nature of infectious pancreatic necrosis in trout. *Proceedings of the Society for Experimental Biology and Medicine, 104(1), 105–108*.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