Aquaculture in the Bay of Plenty

Biosecurity Risk Assessment

Tisbe Client Report 14-0501

May 2014 (Revised June 2014)

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Executive Summary

The Bay of Connections Regional Growth Strategy is focussed on developing a prosperous region driven by sustainable sectors. One goal within the strategy is to support the development of the aquaculture sector to become a $250 million industry by 2025.

Currently there is a relatively small amount of aquaculture activity in the Bay of Plenty, with the industry consisting of an inshore oyster farm, a small paua farm and a large offshore mussel farm off Opotiki (3,800 ha) that is currently under development. The region also supports a nationally important trout hatchery. Aquaculture growth within the region is predicated on the development of a diverse species mix that includes; mussels, pacific oysters, flat oysters, geoducks, sea cucumbers, Koura and potentially eels and trout (subject to legislative changes). This species mix encompasses a range of environments and technologies including; offshore longlines, inshore and intertidal racks, onshore tank and recirculation systems, marine ponds and freshwater ponds.

In 2010 a Regional Aquaculture Organisation (RAO) was established to implement the Aquaculture Strategy. As part of its leadership role in aquaculture development, the RAO considers that developing biosecurity awareness and management is important in underpinning aquaculture development in the region.

In an aquaculture context, biosecurity encompasses the protection of hatchery and culture operations from pests, parasites, and pathogens as well as the prevention of aquaculture operations from affecting external economic and environmental values. The level of biosecurity risk posed by the presence of these organisms varies in relation to the species farmed, the technology used and the characteristics of the pest or pathogen. Understanding this matrix of risks is a critical step in developing an overall risk assessment for the aquaculture industry.

To gain a better understanding of the potential impact that biosecurity events may have on aquaculture development, the Bay of Connections has contracted a desktop study to review all known biosecurity risks and the likely occurrences of any biosecurity events in the Bay of Plenty Region. This report presents the findings of that study.

Within this study 25 marine and freshwater pests and pathogens that can significantly impact on aquaculture developments in the Bay of Plenty have been highlighted. Of these, ten pests/pathogens with recorded impacts on aquaculture and four pest species with potential to impact on aquaculture, are already present within the region. Only four organisms on the list are not yet in New Zealand.

Impacts from pest organisms are largely related to fouling of aquaculture structures that result in stock losses, reduced growth rates and increased operational costs due to increased cleaning or handling requirements. The presence of toxins produced by dinoflagellates can also cause significant losses by preventing stock from being harvested.

Impacts from pathogens primarily relate to stock losses through disease outbreaks. However they also compromise growth rates, reduce market access and market value, and impact on the public's perception of the industry.

In order to assess the potential for aquaculture operations to be exposed to biosecurity risks it is necessary to understand the potential vectors that may bring risk organisms to the farms. A range of vectors were analysed, including; international shipping, domestic shipping, moveable structures, slow moving vessels (e.g. Barges), aquaculture, fishing, recreational boating, aquariums, research activities and natural dispersal. The key transport vectors for the Bay of Plenty region were identified as:

- The unregulated movement of recreational vessels (yachts), structures and slow moving vessels (barges) with hull fouling
- International shipping
- The movement of aquaculture equipment and stock

All of these vectors have been recorded as introducing and/or transferring pests and pathogens in the Bay of Plenty region.

The location of aquaculture activities and the technology applied have a significant bearing on the risk of exposure of an aquaculture venture to pests and pathogens. For instance, mussel lines in open coastal environments have little or no protection from exposure to organisms within that environment, whereas fully recirculated land based systems can operate filtration and sanitisation systems that can give them a very high level of protection.

The aquaculture technology employed, presence of pests and pathogens, and likely transport vectors were input into a risk matrix in order to assess the biosecurity risk to potential aquaculture activities within the Bay of Plenty.

The analysis indicated:

- Offshore mussel farms were almost certain to be exposed to fouling pests that could cause moderate to high economic impacts on production through stock losses and increased handling
- Oyster farms were almost certain to be exposed to the Ostreid herpes virus potentially resulting in major economic impacts through stock losses.
- Offshore fish farms for kingfish and Hapuka were almost certain to be exposed to marine pests that would cause moderate increases in operational costs, and parasites that could cause major losses from mortalities and increased operational costs.
- Sea cucumber and geoduck farming had a possible risk of being impacted by date mussels (smothering) and paddle crabs (predation) causing a moderate economic impact through stock losses.
- Freshwater pond cultures were possibly at risk from pest plants and algae that may smother stock and/or block intake systems causing increased operational costs.

This report does not consider mitigation strategies for these risks. However, it is widely recognised that:

- It is better to try and stop biosecurity incursions than to try and manage incursions once they occur.

- It is much simpler to apply meaningful biosecurity measures in intensive small-scale aquaculture systems than to those in open marine environments.

In order to minimise these risks the following activities should be considered:

- Establish a programme of targeted public education (and signage) to increase awareness of the risks associated with transferring fouled vessels between regions.
- Improve linkages between marinas and harbours in neighbouring regions to alert operators to the movements of fouled vessels.
- Increase awareness amongst commercial operators, particularly those involved with moveable structures and barges, as to the risks associated with moving fouled vessels between regions.
- Increase surveillance of high risk structures/vessels, including swing moorings and barges/moveable structures.
- Increase activity of the Top of the North Marine Biosecurity Partnership to share information on biosecurity risks between regions.

Biosecurity incursions present risks not only to aquaculture, but to a wide range of social activities and environmental values. The aquaculture industry has strong production and marketing incentives to minimise the risks to themselves and to the environment from biosecurity incursions. The presence of pests and diseases not only reduces profitability, but also impacts on the social license for aquaculture operations to become established in public space.

Whilst it is important that the aquaculture industry develops and adheres to biosecurity management plans, this report demonstrates that they are only one small part of the risk profile. Industry activities to minimise biosecurity risks must therefore be in concert with the activities of other marine users and regulatory agencies in order to effectively minimise the risks from all transport vectors that can introduce pests and pathogens to the region.

Contents

1. Introduction

In the past 40 years aquaculture in New Zealand has grown from small beginnings to a significant primary industry, sustainably producing Greenshell mussels, King salmon and Pacific oysters. In 2011 New Zealand's aquaculture sector generated over $400 million in revenue and employed over 3,000 people. New Zealand's aquaculture industry has a target of reaching $1 billion in sales by 2025 (New Zealand Aquaculture 2006).

Growth in the aquaculture sector is a key focus area in the Bay of Connections Regional Economic Development Strategy (Bay of Connections 2011). The Bay of Plenty Aquaculture Strategy, written in 2009 and updated in 2013, forms a key part of this regional strategy. In 2010 a Regional Aquaculture Organisation was launched to implement the Aquaculture Strategy.

The goal of the Bay of Plenty Aquaculture Strategy is: "*To grow an integrated and sustainable aquaculture industry in the Bay of Plenty with export sales of $250 million by 2025".*

Currently there is a relatively small amount of aquaculture activity in the Bay of Plenty. Inshore, there are three oyster farms leases in Ohiwa Harbour (covering 9.6 ha and farmed by Ohiwa Oyster Farm), a small undeveloped mussel farm site in Factory Bay, Te Kaha, and a small land-based Paua farm at Te Kaha. A large offshore mussel farm off Opotiki (3,800 ha) is currently under development with cultivation trials progressing at the site. An application for a 4,009-ha mussel farm off Otamaraku was withdrawn in 2013. There are currently no commercial freshwater fish farms in the region. However, a nationally significant Fish and Game trout hatchery operates at Ngongotaha near Rotorua. The Bay of Plenty Polytechnic and the University of Waikato have research facilities in the region and undertake aquaculture related research on a range of fish and shellfish species.

The Aquaculture Strategy indicates that aquaculture growth within the region is predicated on the development of a diverse species mix that includes; mussels, Pacific oysters, flat oysters, geoducks, sea cucumbers, and potentially eels and trout (subject to legislative changes) (Coates 2011). Other potential species, suited to rearing in the Bay of Plenty region, may include finfish such as Hapuka and kingfish and Kōura (freshwater crayfish). This species mix encompasses a range of environments and technologies including; offshore longlines, inshore and intertidal racks, onshore tank and recirculation systems, marine ponds and freshwater ponds.

One focus area of the Aquaculture Strategy over the next three years is on leadership. This includes "*establishing planning policies and rules that enable aquaculture and provide essential infrastructure services*". As part of this leadership role, the Regional Aquaculture Organisation considers that increasing biosecurity awareness and management are important in underpinning aquaculture development in the region.

Biosecurity can broadly be defined as the exclusion, eradication or effective management of risks posed by pests and diseases (Biosecurity Council 2003). To date, much of the work undertaken on aquaculture and biosecurity has focussed on the potential of aquaculture operations to impact on biosecurity within the marine environment. The Ministry for Primary Industries (MPI) provides an excellent review on ecological effects of aquaculture that includes a chapter on biosecurity in a New

Zealand context (MPI 2013). It is not our intention here to revisit that study, but to focus instead on specific biosecurity risks to aquaculture within the Bay of Plenty region.

Biosecurity risk organisms include animals, plants and micro-organisms capable of adversely affecting natural, traditional or economic values through predation, competition and causing diseases (Arthur et al 2009). In an aquaculture context, biosecurity encompasses the protection of hatchery and culture operations from pests, parasites, and pathogens. These organisms may include non-indigenous species, indigenous species and cryptogenic species (those whose origin is uncertain) that can impact on aquaculture operations (Hewitt et al 2006; Forrest et al 2011). The level of biosecurity risk posed by the presence of these organisms varies in relation to the species farmed, the technology used and the characteristics of the pest or pathogen. Understanding this matrix of risks is a critical step in developing an overall risk assessment and an appropriate risk management strategy.

Pests and diseases can be moved to novel locations in a number of ways. Some movements may be through natural dispersal and others may be caused by human activities (biological introductions). However, once transferred into new marine or freshwater environments, pests and diseases are difficult to contain or eradicate. Understanding potential routes and vectors for the incursion and transfer of biosecurity risk organisms is therefore a key component of preventing and managing incursions. MPI has considered potential vectors for the transport of pathogens related to aquaculture (MPI 2011a) and are currently completing a review of transport vectors for biosecurity risk organisms in the marine environment.

To gain a better understanding of the potential impact that biosecurity incursions in the Bay of Plenty region may have on aquaculture development, the Bay of Connections has contracted a desktop study to review all known biosecurity risks and the likely occurrences of any biosecurity events in the Bay of Plenty Region. This report presents the findings of that study.

2. Biosecurity Risks to Aquaculture in New Zealand

Although the occurrence of pests and diseases in New Zealand's aquaculture industry is low compared to other countries, aquaculture is a valuable coastal industry and consequently considerable effort is expended in both preventing new incursions and controlling the spread of existing pest species.

Despite a relatively large number of introductions of non-native species nationally, only a few species have been recognised as pests that have adverse ecological impacts or economic consequences for aquaculture.

Whilst aquaculture activities can be significantly impacted by pests and diseases these activities can also exacerbate the establishment and spread of pests. Aquaculture structures and stock can provide habitats and hosts for the growth and multiplication of pests and diseases, and many farmed species are non-indigenous. Aquaculture equipment presents a large surface area for fouling by pests. When newly deployed or cleaned, equipment is often colonised by opportunistic and fast growing species, including pest species.

Higher stocking densities and reduced environmental quality associated with some aquaculture activities may adversely affect the immunological condition of stock, making them more prone to disease and facilitating transmission from host to host (MPI 2009). A number of diseases have already been recorded in New Zealand as having impacts on aquaculture stock or as being a serious risk for aquaculture development (Diggles et al 2002).

Once established, pests and diseases in aquatic environments may spread faster than their terrestrial equivalents because of the lack of barriers and the ability of these organisms to survive in water between hosts.

A list of potential pest and disease threats to marine and freshwater aquaculture in New Zealand is provided in Appendix 1 and a summary of those already recorded as having impacts in New Zealand is presented in Appendix 2. Pests and diseases that may present a risk to aquaculture development in the Bay of Plenty are reviewed below and summarised in Table 2.

2.1. Biosecurity Legislation

The intentional introduction of new exotic species into New Zealand is controlled by Central Government under the Hazardous Substances and New Organisms Act 1996 (HSN096). New exotic species cannot be introduced into New Zealand without first gaining authorisation under this Act. However, if authorisation is obtained there are no further controls placed on the distribution of a species once it has been introduced into New Zealand. Likewise HSN096 does not apply to exotic species that have already been introduced into New Zealand.

The Biosecurity Act 1993 (as amended in 1997) provides for Central Government border control for the introduction of new organisms into New Zealand. This function is relevant to the introduction of new species in the ballast water of vessels and is currently implemented by MPI. The Biosecurity Act also addresses the physical control of previously introduced species that have been declared to be pests. This function is implemented in the Bay of Plenty region by Environment Bay of Plenty through regional pest management strategies.

2.2. Pest Management

Whilst the responsibility for managing the introduction and transfer of pests lies with all New Zealanders, the Ministry of Primary Industries (MPI) has a lead role in pest management systems throughout New Zealand. MPI is responsible for developing, monitoring, implementing and reviewing strategic directions in regard to biosecurity. It has developed a National Plan of Action that outlines the policy direction for pest management in New Zealand. The Pest Management National Plan of Action (MAF 2011) sets out the roles and responsibilities for pest management between agencies (including regional councils) and individuals in New Zealand. An overview of the pest management system in New Zealand and the challenges facing effective control and management of pests are discussed by Enfocus Ltd. (2008) and a summary of regional council responsibilities is presented in Table 1.

Specific surveillance strategies for marine pests are based on MPI funded port surveillance programmes (e.g. Inglis et al 2006; Inglis et al 2008), and public and industry awareness campaigns (e.g. The Marine Biosecurity Porthole [www.marinebiosecurity.org.nz]).

In the Bay of Plenty regions, the Regional Council has established “The Regional Pest Management Plan for the Bay of Plenty 2011 – 2016”. This plan makes the following comments in regard to marine pests:

> *“Bay of Plenty Regional Council has adopted the lead intervention decision-maker roles for the marine environment. These roles will form the basis of our response to managing pests in the marine environment.*
>
> *We will also participate in the Top of the North Marine Biosecurity Partnership*[1]*, a regional partnership facilitated by MAF which covers the northern North Island. The partnership aims to prevent marine pest incursions from other parts of the country and minimise the spread of those already established within the northern North Island.*
>
> *We are yet to fully assess marine pest issues or individual marine pest threats likely to be faced in this region. When there is certainty in risks and our operational requirements in managing these risks, this Plan will be updated”.*

[1] The Top of the North Partnership covers the top of the North Island, with members from the Northland, Auckland and Bay of Plenty regions. These include local authorities, central government agencies such as Department of Conservation and Ministry for Primary Industries, the aquaculture industry, the Marina Operators’ Association, technical institutes and iwi. The ultimate focus is on building marine biosecurity capacity to stop the spread of marine pests. The Top of the North Marine Biosecurity Partnership is not currently meeting regularly.

Table 1. Regional council responsibilities for pest management in the marine environment.

Circumstance	Reason for Role
Risk to any national or regional value associated with intra-regional movement of vectors (for example, of structures, equipment and vessels).	Have regional capacity and powers to act in the public interest.
Risk to any national or regional value associated with development of marinas, wharves, jetties and moorings and the on-going maintenance of such facilities.	Have powers under the Resource Management Act (for example, can include conditions in resource consents).
Risk to any national or regional value associated with dumping of organic material from vessels (within the 12 nautical mile limit and on land).	Administer the Resource Management (Marine Pollution) Regulations 1998
Places recognised by formal regional policy as being of special value to regional communities (not being sites as above).	Accountable to regional community and have regional capacity and powers to act in the public interest

2.3. Common Pests and Diseases of New Zealand Aquaculture

2.3.1. Clubbed Tunicate

The clubbed tunicate (*Styela clava*) is a marine pest that was first detected in Auckland in 2005. It has subsequently become established in Northland, Wellington, Nelson, Lyttleton and Dunedin. It has recently been discovered in Picton, where a significant amount of effort is being directed at its eradication.

Styela clava (Styela) impacts directly on a range of sea based aquaculture operations. It is capable of fouling gear and stock to a degree where handling times are increased and control efforts are necessary, thus increasing operational costs. There is the potential for it to cause diminished returns due to poorer condition, through competition for space and food, and increased discards of fouled stock. A recent study indicated that nationally aquaculture losses from Styela could be up to $53.5 million per year (Deloitte 2011).

Styela larvae are free-swimming, but weakly so, and their local spread is largely influenced by hydrodynamics (Bourque et al 2005). Local dispersal is generally gradual and is not considered a primary means by which Styela is spread beyond the immediate areas of introduction.

Styela larvae settle on a variety of potential transport vectors (ships and equipment), most typically those with existing macrofouling. Larvae may also settle on apparently clean aquaculture stock and gear. Translocation of objects on which larvae have settled is the most likely means of further spread. Ballast water taken from an affected area and subsequently discharged less than 24 hours later may also introduce viable Styela larvae to an unaffected port.

Styela is not currently present within the Bay of Plenty Region. However, its presence in the Hauraki Gulf and the frequency of shipping between the Hauraki Gulf and the Bay of Plenty suggests that there is a strong likelihood that this species will occur in the region over time. In recent years commercial and recreational vessels have been found in Tauranga Harbour with Styela amongst biofouling on their hulls. It seems highly likely that Styela will be imported and establish itself in the region through the movement of recreational and commercial vessels from the Hauraki Gulf.

2.3.2. Whangamata Sea Squirt

The invasive colonial ascidian *Didemnum vexillum* (Didemnum) was first identified in New Zealand in Whangamata in 2001. It subsequently spread to Tauranga, Wellington, Nelson, Marlborough sounds and Lyttleton. Its establishment has led to negative effects on mussel culture, particularly within the Marlborough Sounds region, which is New Zealand's most important growing area for mussels.

The impact of Didemnum on mussel farms includes increased operational costs due to fouling and loss of mussels. Fletcher et al (2013b) found that the mussels themselves were only vulnerable to direct Didemnum fouling impacts during the early stages of production, and that impacts were restricted to displacement of mussels as opposed to a reduced size and condition.

Didemnum colonies are capable of rapid growth and expansion through both sexual and asexual reproduction, and as such are able to quickly colonise large areas of artificial and natural substrata (Coutts & Forrest 2007). The spread of Didemnum between regions is largely through human mediated vectors. The larval stages have the ability to spread by natural dispersal over an area of hundreds of metres to kilometres, depending on the local hydrological conditions (Fletcher et al 2013a)

Didemnum is already present within Tauranga harbour and may be present within other ports within the Bay of Plenty. It does not appear to have had any significant economic impacts in the harbour (Sinner et al *2011).*

Didemnum has not been detected on trial mussel lines at the Opotiki mussel farm (K Heasman pers. comm.*).*

2.3.3. Eudistoma elongatum

Eudistoma elongatum (Eudistoma) is an Australian native ascidian (sea squirt) which forms large colonies or groups that attach to hard surfaces. Eudistoma was first reported in New Zealand in early 2005, but was not regarded as a significant pest at that time given its low density and the fact that it appeared to die off over winter. It is not regarded as a serious nuisance to the aquaculture industry or the environment in its native Australia.

In the summer of 2007/08 the species became more prolific in a number of Northland locations and has continued to appear each year over the summer months. It has been recorded as smothering oyster racks, and may therefore impact on aquaculture through increases in labour costs for cleaning of equipment.

The larvae of Eudistoma swim for only 6 hours, indicating that the dispersal of this species requires human mediated vectors. Eudistoma was found to reproduce at temperatures above 14^{o}C indicating that it may spread to more southerly harbours than those included in its current range in New Zealand (Page et al 2011).

Eudistoma has historically been reported in Tauranga harbour (www.biosecurity.govt.nz/pests/eudistoma-elongatum) but has not been present in recent years and was not found in the 2006 Marine surveillance programme (Inglis et al 2008). Winter water temperatures within Tauranga and the Bay of plenty are towards the lower end of the thermal tolerance of this species.

2.3.4. Mediterranean Fanworm.

The Mediterranean fanworm (*Sabella spallanzanii)* is a marine worm that is typically found in estuaries or sheltered sites, at depths between one to 30 metres. The arrival and apparent establishment of the fanworm in New Zealand is ascribed to accidental international transfer probably in 2007, when it was first found in Lyttelton and Auckland. The transport vector for introduction is thought to be either via hull fouling or ballast water. It is not known if the two ports were colonised via the same transiting vessel (Read et al 2011).

Fanworms can form dense groups that could affect native species by competing for food and space. Recent studies have also indicated that it can impact on the establishment of new generations of some species, and on nutrient flow. The presence of dense mats of this species could also have an impact on the aesthetics of an area for diving, potentially impacting on dive tourism activities. While they have not yet been recorded to have had significant impacts on fisheries or aquaculture in New Zealand, there is potential that dense colonies could become a nuisance through fouling of equipment.

Fanworm larvae reared in the laboratory can remain pelagic for 14 days (Giangrande et al 2000), suggesting that dispersal vial local currents over distances of several kilometres or more may be possible. The larvae may also survive in ship ballast water, enabling dispersal between New Zealand ports.

To date fanworms have been recorded in Auckland, Whangarei and Lyttleton harbours and single specimens were recently found in Tauranga Harbour and in Picton associated with vessels on swing moorings.

The presence of a single fanworm in Tauranga Harbour in 2013 illustrates the potential for this species to spread from the Hauraki Gulf, probably as part of the fouling assemblages on recreational or commercial vessels.

2.3.5. Asian Paddle Crab

The Asian paddle crab (*Charybdis japonica*) is a swimming crab native to South East Asia. It is normally found in the waters of Japan, Korea and Malaysia. It is typically found in estuaries where there is firm sand or muddy fine sand.

This crab was first reported in New Zealand in Auckland in late 2000. It is now widespread in the Waitemata Harbour and the wider Hauraki Gulf. A single specimen was found in Whangarei Harbour in 2003, and in 2009, two further specimens were found in this harbour.

This aggressive crab has the potential to compete with native crabs for space and food. It is a potential threat to marine farming as it preys on shellfish and other aquaculture species (Fowler 2011). It is also known for its aggressive temperament and can inflict a vicious bite if disturbed. It is not reported to be a pest in its native habitat or in other countries.

Adult paddle crabs can produce hundreds of thousands of offspring. The larvae can float in the water for three to four weeks, during which time they can be moved large distances by tides and currents. Adults are also capable of swimming large distances.

Human activities associated with boating, shipping, fishing and marine farming could increase its rate and distance of spread, either as a hitchhiking pest on marine equipment, or as larvae in ballast water or bait tanks.

The Asian paddle Crab is not currently present within the Bay of Plenty Region. However, its presence in the Hauraki Gulf and the frequency of shipping between the Hauraki Gulf and the Bay of Plenty suggests that there is a strong likelihood that this species will occur in the region over time.

2.3.6. Triangle Barnacle

The Triangle barnacle (*Balanus trigonus*) is a cryptogenic barnacle that has become a fouling pest on cultured mussels in the Firth of Thames. The proliferation of this barnacle appears to have occurred only over the last 1-2 years, despite the species being described in the Hauraki Gulf for many decades

The presence of the barnacle on mussel shells impedes processing operations (A Jeffs pers. comm.), and leaves a scar on the mussel shell which decreases marketability and value.

The Triangle barnacle is recorded as being present in the Bay of Plenty, but has not been observed on the trial offshore mussel lines at Opotiki to date.

2.3.7. Asian Date Mussels

The Asian date mussel (*Musculista senhousia*) is small (up to 3 cm) and brown to green in colour. It lives in shallow and calm areas of harbours and estuaries. Young date mussels secrete tiny threads which attach to sand grains and join with those from neighbouring mussels to form a thick, hard mat. These mats can prevent other shellfish species and sea grass from growing. The mats survive for one or two years before they die or drift to somewhere else.

Date mussels have a relatively long larval life (15-18 days) (Sgro et al 2002) enabling them to drift for considerable distances. Human activities associated with boating, fishing and marine farming could also mediate their spread, either as a hitchhiking pest on marine equipment, or as larvae in ballast water or bait tanks. In Australia transfer of aquaculture equipment and seed stock is considered a high-risk vector for transferring date mussels, with oyster farming activities considered the most likely to mediate the transfer of this species between regions.

The Asian date mussel is present in Tauranga harbour.

2.3.8. Undaria

The kelp *Undaria pinnatifida* (*Undaria*) is native to Japan where it is cultivated for human consumption. It is a highly invasive opportunistic seaweed which spreads mainly by fouling on boat hulls. It can form dense stands underwater, potentially resulting in competition for light and space which may lead to the exclusion or displacement of native plant and animal species.

Undaria was accidentally introduced to New Zealand waters in the 1980s. It is firmly established in many areas, but it is still officially designated an unwanted organism and is the subject of local elimination programmes in Fiordland and on the Chatham Islands.

Undaria is present in almost all of New Zealand's international ports and harbours ranging from Auckland down to Bluff including Stewart Island and, recently, the Snares, Fiordland and Chatham Islands. It is also found along the top of the South Island.

Undaria spores are viable in culture for extended periods, but dispersal studies indicate that discreet populations can expand by only a few hundred meters each year (Sliwa et al 2006). The major vector for the spread of Undaria therefore appears to be human mediated, probably as sporophytes fouling vessel hulls.

Undaria plants are opportunistic colonisers often growing on the upper parts of mussel ropes, adding biomass to the line and increasing labour requirements for cleaning and harvesting stock.

In early 2012, MPI announced three areas where farming of Undaria will be allowed, subject to MPI approval. The areas are in waters of Wellington, Marlborough, and Banks Peninsula. Undaria may also be harvested if it is a fouling organism on aquaculture equipment.

Undaria is already present within Tauranga harbour. It may be present within other ports within the Bay of Plenty but is not recorded on the outer coast of Whakatane Harbour (Bioresearches Ltd. 2013) or on trial mussel lines at the Opotiki mussel farm.

2.3.9. Ostreid Herpes Virus (OsHV-1)

Ostreid herpes virus is a virulent viral disease of the Pacific oyster (*Crassostrea gigas*). Although the virus has been detected in other shellfish, oysters are the only species of shellfish currently known to be susceptible to mortalities from this virus.

Mortalities from virus outbreaks appear to be temperature dependent, only occurring when water temperatures exceed 16^{o}C. The highest mortalities occur in juvenile oysters, however, all life stages are thought to be susceptible to infection. Adult mortality varies between 10 - 30 %, and juvenile mortality is between 60 - 100 %.

The virus may have been present in New Zealand waters since at least 1991 but it did not show itself in farmed or wild stocks until 2010. This was possibly due to stress caused by unusually high summer water temperatures (MAF 2010).

In the summer of 2010/11 the Ostreid herpes virus was identified as a cause of a 30 to 80 % die-off of oyster spat in most North Island harbours. Wild spat showed 50 % mortality while the mortality of hatchery reared spat was up to 100%.

Transport vectors have not been clearly identified, but the spread of the virus is most likely to be a result of transferring oyster seed stocks between spat catching sites and on-growing areas.

The Ostreid herpes virus has been recorded within the Bay of Plenty region, causing significant mortalities within oysters at the Ohiwa oyster farm.

2.3.10. Monogeneans

Parasitic infections of fish can affect their growth, reproduction and in extreme cases cause significant mortalities. Globally, aquaculture industries involved with commercial culture of kingfish (Seriola spp.) commonly experience outbreaks of monogenean parasites, which can cause heavy stock losses. The monogenean parasites *Benedenia seriolae* and *Zeuxapta seriolae* have been shown to pose a significant risk to Kingfish aquaculture. *B. seriolae* is currently regarded as the highest potential threat to cost-effective sea-cage farming of kingfish in Australia (Hutson et al 2007).

Both *Benedenia seriolae* and *Zeuxapta seriolae*, have been isolated from wild and farmed kingfish in New Zealand, including the Bay of Plenty (Sharp et al 2004). It is considered that these infections of farmed fish generally occur as a result of direct interaction with wild fish or the presence of larval stages of the parasites in the coastal marine environment.

Monogenean parasites are present within wild kingfish populations in the Bay of Plenty.

2.3.11. Uronema

The ciliated protozoa *Uronema marinum* has been isolated from Hapuka (*Polyprion oxygeneios*) grown in Northland and Wellington. It is likely to be ubiquitous throughout wild populations of Hapuka.

In cultured Hapuka this ciliate was found in high densities and caused significant mortalities in fish as large as 500g.

Uronema is likely to be present throughout New Zealand. Cage cultured Hapuka are unlikely to come into contact with wild Hapuka, and transfer is therefore most likely to be in association with stock and equipment.

2.3.12. Whirling Disease

The most prominent freshwater disease relating to aquaculture in New Zealand is whirling disease caused by the parasite *Myxobolus cerebralis*. It was first found in New Zealand in 1971. To date the parasite has only been found in rivers in the South Island, away from the most important aquaculture sites.

The disease causes mortalities in young fish and affects the ability to export fish from infected sites (Anderson 1996)

The disease predominantly affects salmon and trout. However, the salmonid species commercially cultured in New Zealand have low susceptibility to whirling disease, and the parasite has not been shown to affect native fish. There is concern that the disease may become established in trout populations.

Whirling disease is not known to be present in the North Island. Transport to the Bay of Plenty would appear to require human mediated vectors such as transport of infected fish or equipment.

2.3.13. White Tail Disease

The only disease known to seriously affect Kōura (freshwater crayfish) is white tail disease. This disease is caused by the microsporidian parasite *Thelohania contejeani*. This parasite causes degeneration of striated muscle in the tail area of the Kōura and this turns the tail a pale white colour, leading to death soon after. This parasite has not been recorded in the North Island (Quilter 1976).

White tail disease is not known to be present in the North Island. Transport to the Bay of Plenty would appear to require human mediated vectors such as transport of infected fish or equipment

2.3.14. Dinoflagellates

The term dinoflagellates encompass a wide range of motile phytoplankton species, some of which are capable of producing toxins that are harmful to shellfish, fish or humans. Under the right set of environmental conditions blooms of dinoflagellates can occur, producing sufficient toxin to cause fish kills and to render seafood poisonous to humans. Consequently, the New Zealand aquaculture industry closely monitors toxin levels and the presence of dinoflagellate species and stops harvesting shellfish when toxins are detected (Rhodes et al 2013). Persistent blooms of toxic dinoflagellates can prevent shellfish harvesting for extended periods and pose a significant economic cost to the industry. Introduced species of dinoflagellate have the potential to outcompete native species, leading to an increase in the occurrence of toxic algal blooms.

Some species of dinoflagellates are capable of forming resting stages known as “cysts” when conditions are not favourable for growth. These stages may remain dormant for extended periods and consequently have the potential to be transported considerable distances in ballast water (Hallegraeff 1998).

A number of toxic dinoflagellate species have been recorded in the Bay of Plenty region, including Alexadrium minutum that caused a paralytic Shellfish Poisoning event in 1993 (Chang et al 1997). Resting cysts of Protoceratium reticulum and Lingulodinium polyedrum, that are known to produce toxins that cause diarrhetic shellfish poisoning, have been identified in sediment samples from Tauranga Harbour (Inglis et al 2006).

Table 2 Summary of key pest and disease risks to New Zealand Aquaculture

Organism	Nature of Impact	Locations
Clubbed Tunicate (*Styela clava*)	High-density fouling of aquaculture equipment, competition with farmed species for resources and overgrowth of shellfish.	Northland, Auckland, Wellington, Nelson, Picton, Lyttleton, Dunedin
Whangamata sea squirt *(Didemnum vexillum)*	High-density fouling of aquaculture equipment.	Whangamata, Tauranga, Wellington, Nelson, Marlborough sounds, Lyttleton
Eudistoma elongatum (sea squirt)	Forms large colonies or groups that attach to hard surfaces. It is not regarded as a serious nuisance to the aquaculture industry in its native Australia.	Bay of Islands, Whangarei Harbour, Tauranga Harbour (historically), Picton (historically)
Mediterranean fanworm (*Sabella spallanzanii)*	Form dense groups that affect aquaculture by competing for food and space.	Whangarei ,Auckland, Lyttleton, Tauranga, Picton
Asian paddle crab (*Charybdis japonica*)	Preys on shellfish and other aquaculture species.	Northland, Auckland.
Triangle barnacle (Balanus trigonus)	Fouls mussel shells increasing processing costs	Throughout NZ
Asian Date Mussel (*Musculista senhousia*)	Modifies seabed habitat, impacting on benthic shellfish	Northland, Auckland, Tauranga
Undaria (*Undaria pinnatifida*)	Fouling of aquaculture equipment.	Throughout New Zealand, but rare in Northland.
Oyster herpes virus (OsHV-1)	Significant mortalities in juvenile Pacific oysters	Northland, Auckland, Bay of Plenty
Monogeneans	Parasites of marine fish, reduces growth and causes mortality	Throughout NZ
Uronema	Ciliate parasite of marine fish. Reduces growth and causes mortalities particularly in farmed Hapuka	Throughout NZ
Whirling Disease (*Myxobolus cerebralis)*	Salmonid parasite. Causes mortalities	South Island only.
White Tail Disease (*Thelohania contejeani*)	Parasite causes significant mortalities in Kōura.	Dunedin
Dinoflagellates	Produce toxins harmful to fish and humans.	Throughout NZ

2.4. Freshwater Pests that may Impact on Aquaculture

New Zealand's freshwater environment contains a large number of pest species. Over 200 freshwater plant and animal species have been introduced to New Zealand, many of which have naturalised and become pests, or have the potential to become pests. Impacts from these species are significant, including reduction in indigenous biodiversity, destabilisation of aquatic habitats, implications for human health, economic losses through lost power generation, impeded drainage or irrigation, and reduced opportunity for recreational activities. Freshwater pests include; fish (9 species), invertebrates (11 species), algae (2 species) and aquatic weeds (39 species) (Champion et al 2012). However, there is no documented evidence to suggest that these organisms are currently impacting on aquaculture activities in New Zealand.

Freshwater aquaculture activities in New Zealand are controlled under the Resource Management Act (RMA) and are licensed through MPI under the Freshwater Fish Farming Regulations 1983. These regulations require operators farming freshwater and marine species, on shore, for sale, to be licensed. The regulations gazette 53 organisms that can be farmed, of which 19 are invertebrates and 3 are plants/algae. Only 6 freshwater species are gazetted. The gazetted list does not include trout (6 hatcheries used for stocking lakes and rivers), or any species that are currently considered as ornamental species (e.g. Goldfish, tropical aquarium fish, axolotls, frogs or aquatic plants such as lilies). The Current list of licenced fish farms includes approximately 80 farms and research facilities of which 19 are currently inactive or not stocked. The list of species currently farmed includes seven freshwater species (Grass carp [4 farms], Salmon [16 farms], Perch [1 farm], Eel [1 farm], Goldfish [1 farm], Kōura [17 farms], Malaysian prawn [1 farm]. A wide range of organisms, including plants, invertebrates and temperate and tropical fish species, are therefore cultured for sale in New Zealand without their production being regulated under the 1983 Freshwater Fish Farming Regulations.

Biosecurity for pet stores and aquatic plant nurseries is administered by industry bodies and through regional councils under the National Pest Plant Accord. However, there remain a significant number of producers of freshwater organisms that are un-regulated. MPI is currently completing a survey of unlicensed land based aquaculture practices with regard to identifying the likely biosecurity risks associated with this activity. In this section, only risks linked to farms producing freshwater species and not land based marine farms will be considered.

Freshwater pests that may impact on aquaculture development include plants, invertebrates, fish species and disease causing pathogens and parasites. The primary risk from invasive weeds and algae centres on their potential to grow quickly and block intakes. This can result in reduced water flow to stock and reduced water quality, leading to slow growth and mortalities.

There are not currently any active licenced freshwater fish farms operating within the Bay of Plenty region. However, Fish and Game operate a trout hatchery and nursery ponds at Ngongotaha near Rotorua. Future developments may include eel, goldfish, Kōura and trout farms. These farms may be based on pond, flow through tank, or recirculation systems. Pest species that are currently within the Bay of Plenty region, and those that may impact on aquaculture, but are not currently in the region, are reviewed below.

2.5. Freshwater Pests in the Bay of Plenty Region

Lakes and river systems in the Bay of Plenty contain a number of pest plant and algae species. Most lakes contain *Elodea canadensis (Canadian pondweed)* and *Lagarosiphon major (Lagarosiphon)*. *Ceratophyllum demersum (Hornwort) Azolla pinnata* and *Egeria densa (Egeria)* are also present in a number of the lakes. The invasive algae, *Hydrodictyon reticlatum* (water net), is naturalised in the region. Of these species, only Hornwort and water net may be considered to have the potential to impact significantly on freshwater aquaculture developments.

In addition fish (e.g. *Gambusia*) and water snail species present within the regions also pose potential threats as predators and/or carriers of pathogens.

2.5.1. Hornwort

Of the plant species listed above, hornwort (*Ceratophyllum demersum)* potentially poses the largest threat to aquaculture. Hornwort out-competes and smothers other (native and introduced) plant species and has the ability to grow to heights over 10 m in very dense surface reaching weed beds. These may become detached posing a hazard to recreational users and obstructing intakes.

Hornwort is easily spread. A single fragment carried on a boat trailer, fishing gear, anchor or a float plane can easily be carried to another lake (Matheson et al 2005). Considerable effort is expended in the region on surveillance and control of invasive weeds to prevent further incursion of hornwort. These include public awareness campaigns, stakeholder engagement activities, surveillance and incursion management activities around boat ramps.

The existence of hornwort in the region poses a significant risk to development of pond based aquaculture activities.

2.5.2. Water Net

Water net *(Hydrodictyon* reticulatum) is a green filamentous algae. It is distinctive in appearance, with individual cells joined to form a six-sided mesh which makes up colonies. Water net was first reported in New Zealand in 1986 near Tauranga. By February 1989 water net had spread from the initial infestation site to Lake Rotorua and Lake Rotoiti, with its range continuing to expand through the Bay of Plenty and the Waikato region over the next few years.

Extensive floating mats interfere with recreational activities, degrade the aesthetic values of water bodies and accumulate in decaying drifts on beaches. Smothered macrophyte beds become prone to collapse and subsequent decay. Surprisingly, many invertebrates and trout appear to benefit from the water net blooms, with the nets supporting large populations of invertebrates. Marked boom/bust behaviour of water net is common (Wells et al 1999).

Water net can establish from a single cell or from spores. Agents of dispersal include wind and water movements, wildfowl, insects, livestock and humans. The aquarium and pond plant industry, movement of machinery, and boating and fishing are all likely to have contributed to its current distribution (Champion et al 2013).

Water net blooms may block aquaculture intakes or cause smothering and oxygen depletion (through decaying material) in ponds.

Water net is naturalised in the Bay of Plenty region through blocking of intakes and/or oxygen depletion in ponds.

2.5.3. Gambusia

Gambusia (*Gambusia affinis)* is present within the Bay of Plenty region. This species is often referred to as mosquito fish due to the mistaken, yet unfortunately widespread belief that they can control mosquito populations.

The first shipment of Gambusia from the Gulf of Mexico to New Zealand was released into an Auckland Botanical Gardens pond in the 1930s. Little information about successive releases is available, but further transfers into Northland, Taranaki and Wellington in the 1930s are documented. Since then, Gambusia has continued to increase their range in many North Island waterways due to natural spread and by further illegal introductions (DoC 2014).

Gambusia are aggressive and frequently attack native fish, nipping at their eyes and fins. Endangered galaxiids and mudfish are especially vulnerable. Gambusia also competes with native fish for food, and have been known to eat native fish eggs.

Gambusia incursions into aquaculture ponds have been recorded as having impacts on growth and survival of juvenile farmed fish (Rincón et al 2002) that reproduce within production ponds, but are regarded as having little impact on ponds that are stocked with larger fish (Mischke et al 2013).

The presence of Gambusia in the Bay of Plenty poses a potential threat to the development of freshwater aquaculture. However, this is likely to be limited to pond culture operations and then only to those stocking small juvenile stages.

2.5.4. Freshwater Snails

Freshwater snail species have been recorded as intermediate hosts for a number of fish and human parasites and pathogens. Seven non indigenous snail species are recorded in New Zealand with three occurring in the Bay of Plenty Region (*Lymnaea auricularia, Lymnaea stagnalis, Physa acuta*) (Champion et al 2013). Dispersal of snails appears to be through release from domestic aquariums and through transfer of pond weeds and plants that have snails attached.

There is no recorded incidence of the non-indigenous freshwater snails found in New Zealand carrying parasites or diseases that impact on aquaculture activities. It is therefore unlikely that they pose a significant risk to aquaculture development in the Bay of Plenty region.

2.6. Other Freshwater Pests that may Impact on Aquaculture

A number of freshwater pest species present in New Zealand, but not present in the Bay of Plenty region have potential to impact on aquaculture development.

2.6.1. Didymo

Didymo (*Didymosphenia geminata*) is an invasive species of benthic microalgae that was first detected in the lower Waiau and Mararoa Rivers in the South Island in October 2004. The alga forms dense mats on the substrate of rivers and around the edges of lakes. Didymo has the capacity to affect ecological processes (e.g. ecosystem metabolism, nutrient cycling) and properties (e.g. species diversity, nutrient pools, population sizes) but has not significantly impacted on native fish populations (Kilroy et al 2009).

Didymo also has the potential to interfere with hydroelectric and irrigation schemes. An assessment undertaken by the New Zealand Institute for Economic Research estimated that for the period 2004/05 to 2011/12 didymo would cost New Zealand between $58 and $285 million (Branson 2006). Didymo thrives on the cement substrate of canal systems and can alter water quality parameters. It therefore has the potential to significantly impact on aquaculture in both pond and tank systems (www.envirothonpa.org/pdfs/didymo.pdf).

There is no evidence yet of any spread of Didymo to the North Island, but research has shown that didymo has the ability to grow in conditions that emulate the water chemistry of rivers from throughout New Zealand, both the North and South Islands. There is therefore potential for didymo to have significant impacts on aquaculture should it become established in the Bay of Plenty region.

2.6.2. Other Invasive Smothering Weeds

A number of invasive weed species have the potential to pose a risk to aquaculture development through clogging of intake systems, reducing water flow to ponds or tank based farms (see Champion et al 2013).

Of the plant pest species that are not currently within the Bay of Plenty region, probably Hydrilla (Hydrilla verticillata) poses the greatest biosecurity threat to aquaculture development. Hydrilla is naturalised in the Hawkes Bay area and is potentially more competitive than hornwort.

Many of the pest plant species in New Zealand are slow to spread and require human mediated transmission (e.g. Arrowhead, Sagittaria saittifolia, eel grass and various water lily species) and are therefore unlikely to pose a major risk to aquaculture developments in the region.

2.6.3. Pest Fish

A number of pest fish species, including Koi carp, rudd, perch, tench and catfish are present in the regions surrounding the Bay of Plenty. With the exception of a recent discovery of a dead catfish, these species have yet to be found within the region (EBoP 2009).

Although there is a high risk of incursion of these species into the Bay of Plenty region their potential impact on aquaculture development is likely to be limited. These relatively large and slow growing species will be easy to detect in aquaculture systems and (possibly with the exception of catfish) would struggle to compete with carnivorous cultured fish reared at commercial densities. Annual harvesting and draining of pond systems would also remove pest fish and prevent large populations of these species from becoming established.

2.7. Pests Not Currently in New Zealand that may Impact on Aquaculture

Biosecurity New Zealand list four pests not currently in New Zealand that they consider as a potential threat to aquaculture, fishing and marine environments. Considerable effort is employed in boarder surveillance in order to minimise the risk of these species being introduced to New Zealand.

It is beyond the scope of this project to comment on the likelihood of incursion of these species, but the potential consequences to aquaculture of incursions, should they occur, are outlined below.

2.7.1. Chinese Mitten Crab

Chinese mitten crabs (*Eriochier sinensis*) are native to China where they are farmed for their meat. This species has invaded Europe and America where it is considered to be a significant pest. Chinese mitten crabs have been recorded as having a range of impacts. These include; burrowing into estuary banks and causing accelerated erosion, damaging fishing nets and blocking water intakes in irrigation and water supply schemes. The crabs also host a liver fluke (*Paragonimus sp.*) that is harmful to human health (Rudnick et al 2000). The potential impacts of Chinese mitten crabs on aquaculture are not clearly understood, but as shellfish predators they may significantly impact on farmed juvenile oysters held on sticks, causing mortalities and requiring a change in farming practices. It is unlikely that they would be able to easily access shellfish held in suspended culture or in trays and therefore may not significantly impact on shellfish farms using these culture techniques.

2.7.2. Northern Pacific Seastar

The Northern Pacific Seastar (*Asterias amurensis*) is a voracious predator of native species and will consume economically important farmed shellfish. It is considerate to have the potential to have serious impacts on aquaculture, fisheries and wild shellfish populations (Ross et al 2002). In Australia, populations of the North Pacific Seastar have caused significant impacts (up to 50% mortality) on commercial scallop populations through predation on spat (Hutson et al 2005). The seastar is a benthic feeder and it is therefore unclear as to the potential impact it may have on shellfish held in suspended culture or in trays. However, it may impact on juvenile oysters held on sticks, requiring changes in farming structures or management systems.

2.7.3. European Shore Crab

The European shore crab (*Carcinus maenas*) is a voracious predator, consuming mussels, crabs, oysters, limpets, barnacles, and worms. It preys particularly on juvenile crabs and shellfish, including scallops. It has the potential to significantly alter ecosystems, causing mortality in native crab and shellfish populations. Shore crabs have been implicated in the decline of native shellfish populations overseas, some of commercial importance. It has been suggested that the lack of major economic impacts caused by the European shore crab in Australia is due to the fact that the main aquaculture species (oysters, mussels) are farmed in cages or on lines that are suspended above the bottom (Proctor 1997) and are therefore not accessible to the crabs. Where impacts have occurred, such as in the oyster industry, changes in equipment and stock management practices have effectively minimised the problem.

2.7.4. Asian clam

Asian clams (*Potamocorbula amurensis*) can occur at high densities, reducing planktonic food sources. In America invasive Asian clams have caused a decline in abundance and diversity of native species, and a decline or collapse of commercial fisheries (Carlton et al 1990). There are no recorded impacts of Asian clams on aquaculture, although it is conceivable that large populations may reduce the availability of food for farmed shellfish. The introduction of Asian clams may impact on aquaculture in the Bay of Plenty by competing for food resources with farmed shellfish. However, offshore farms are less likely to be impacted by populations of invasive clams, as they tend to favour nearshore and estuarine habitats.

3. Transport Vectors for Pests and Diseases

A large range of natural and human mediated pathways exist that can introduce pest and diseases in New Zealand and subsequently disperse them from the point of incursion to other regions. Understanding potential routes of entry and dispersal is critical in controlling biosecurity risks to aquaculture.

Hewitt et al (2004) provide a list of known vectors for the transport of pests and diseases (Table 3). These include ballast water, hull fouling, sea chests, released aquatic pets and plants, aquaculture equipment and products (e.g. Hitchhiker parasites and diseases), intentional release, and natural dispersion. In particular, shipping and the movement of marine farming equipment have been identified as important vectors for human-assisted transfer of harmful marine organisms around the globe (Ruiz et al 2000; Lewis et al 2003; Hewitt and Campbell 2010).

Whilst preventing the introduction of new pest species is clearly a high priority, preventing the dispersal of established pest species into new areas, particularly those where the pest will impact on sensitive environments or economically important activities must also be a high priority (Deloitte 2011). Consequently, it is important to consider not only international transport vectors, but also those of a more local nature.

In this section we shall consider the likelihood of a range of vectors to introduce pests and diseases to New Zealand or spread marine and freshwater pests and diseases to the Bay of Plenty region. The risk level associated with each vector is summarised in Table 4.

Table 3. List of international and domestic pathways of relevance to New Zealand (Hewitt et al 2004)

Category	Pathway
Ships	Ballast water and sediments Hull fouling
Moveable structures (Oil platforms, barges, dredgers, floating docks)	Solid ballast Hull fouling Ballast water and sediments
Other craft (Merchant, fishing, and recreational/leisure)	Hull projections and cavities (Sea-chests, thrusters, and internal piping) Hull boring Aquatic cargo (wells and tanks) Anchor/anchor chains/lockers/moorings Scuppers and bulwarks Small craft trailers Dredging spoil
Aquaculture fisheries	Intentional release and stock movements Accidental release Gear movement Discarded nets, floats, traps Discarded packaging materials Discharge of feeds (live, fresh, and frozen) Release of transgenic and GMO species
Wild fisheries	Stock movement Population re-establishment Processing of live, fresh, and frozen products Live bait movement Gear and transport media (water) movement Discarded/lost fishing gear Discard of target and non-target species (bycatch) Live trade for consumption: accidental/intentional release
Aquarium industry and public aquaria	Intentional release Accidental release Untreated aquarium and waste discharge Living food movement
Marine leisure tourism	Live bait movement Accidental/intentional transport and release of catch Diving gear movement Fishing gear (including boots) movement
Research and education	Intentional release Accidental release Water and waste discharges Living food movement Diving gear movement Field and experimental gear movement Restoration, mitigation and rehabilitation
Other	Alteration of water courses and flow regimes Irrigation canals (including saline ponds) Municipal and waste/water treatment discharges

3.1. International Shipping

Vessels arriving from outside New Zealand's territorial waters have the potential to be vectors for exotic pests, disease agents and unwanted organisms (see for example Inglis et al 2012). These organisms may be transported as hull fouling, in ballast water or in sea chests. MPI operates a standard "Requirements for Vessels Arriving in New Zealand (2010)" that seeks to minimise the risks associated with international vessel movements.

The requirements include Import Health Standards (IHS) for ballast water and for hull fouling.

> *"Vessels must comply with the Import Health Standard for Ships' Ballast Water from All Countries with respect to ballast water loaded in the coastal waters of any country other than New Zealand and which they intend to discharge in New Zealand territorial waters. For most vessels needing to discharge ballast in New Zealand, this will involve the exchange of ballast water in all tanks intended for discharge. The exchange must be with ocean water at least 200 nautical miles from any coast and in water over 200m deep"*

> *"The IHS for vessel biofouling gives the requirements for hull fouling as a risk for transferring marine pest organisms. In addition to any specific requirements, good hull maintenance is encouraged. Vessel hulls, including recesses around rudders and water intake/outlets (sea-chests), should be kept free from excessive growth of seaweed, barnacles, shellfish and other encrusting marine life. Antifouling coatings should be in good condition and renewed before the expiry of the paint manufacturers' recommended replacement period."*

The port of Tauranga is the largest port in the country in terms of total cargo volume, and the second largest in terms of container throughput. For the year ended 30 June 2013, 1,529 vessels called at the Port of Tauranga bringing in over 6 million tonnes of cargo. Cargo came from all over the world, but the largest cargo imports came from Asia (>2 million tonnes). A significant amount of cargo also arrived on vessels that had previously called in at other New Zealand ports (>1.4 million tonnes) (Figure 1).

The port of Tauranga has historically been subject to biosecurity incursions. A baseline and follow up survey for non-indigenous species in the Port was undertaken in 2002 and 2005 (Inglis et al 2006; Inglis et al 2008). The initial survey found 302 species, of which 10 were non-indigenous species and 51 were cryptogenic species (those whose geographic origins are uncertain). During the repeat survey, 264 species were recorded, including 9 non-indigenous species and 43 cryptogenic species. Many species were common to both surveys. The study concluded that approximately 44 % (4 of 9 species) of the non-indigenous species in the Port of Tauranga are likely to have been introduced in hull fouling assemblages, 44 % (4 species) by hull fouling or ballast water, and 1 species (12 %) via fouling on flotsam vectors. Many of the species present in Tauranga were also present in other parts of New Zealand, and it is unclear how many may have directly arrived in the port from overseas vessel traffic.

Currently there is no routine monitoring of fouling associated with vessels entering Tauranga or other New Zealand ports (J Roberts pers. comm.).

Although the level of international shipping traffic entering the Port of Tauranga is high, the improved biosecurity protocols surrounding overseas vessels entering New Zealand waters are a significant factor in controlling the arrival of invasive organisms. However, the absence of routine monitoring makes the effectiveness of these controls hard to assess. Therefore, it must be considered that there remains a moderate to high risk of a biosecurity incursion through this vector.

Figure 1. Major routes of international vessels to and around New Zealand in 2002 (Dodgshun et al 2007)

3.2. Domestic Shipping

Domestic shipping activity provides a potential vector for translocation of marine pests and diseases between ports. Such vessels are unlikely to remain within a single port for a sufficient period to accumulate a significant amount of hull fouling. However, they do provide other vectors for transport, such as ballast water and anchoring systems.

Although New Zealand regulates ballast water exchange for international vessels entering the country, no such standards exist for internal movements. There is significant potential for organisms to be transported in ballast water taken up from an affected area and subsequently be discharged in another port. For example, viable Styela larvae may be transported in ballast water from an affected port to an unaffected port in less than 24 hrs.

Vessels anchoring in infected areas may transport pests attached to sediments on anchors and anchor chains.

Tauranga hosts a significant amount of domestic shipping traffic, including international traffic where Tauranga is not the first port of call. Vessels rarely anchor within the Harbour, although anchoring was more frequent during the Rena salvage operations (J Roberts pers. comm.).

Given the proximity of Tauranga to Auckland, the potential for commercial vessels to translocate pests between the two ports must be considered as high.

3.3. Moveable Structures and Slow Moving Vessels

Moveable structures and slow moving vessels include items such as barges, dredgers and floating docks that tend to remain moored in one area for extended periods of time. Structures that are not moved or maintained regularly have a tendency to become fouled and these fouling organisms may be transported to new areas when the equipment is moved.

Often structures are moved to enable hull cleaning or repairs to be undertaken in areas with more suitable facilities. Consequently heavily fouled structures may be deliberately moved between regions and moored for periods of time whilst waiting for cleaning or repairs.

A study on hull cleaning techniques and facilities (Floerl et al 2004) found that a high proportion of fouling organisms remained viable if hulls were cleaned by diver and that land based cleaning with recovery and treatment of the wastewater was the most effective way of removing pest organisms without increasing biosecurity risk. However, Coutts et al (2010) notes that the process of lifting vessels out of the water for land based cleaning risked fouling species becoming detached from the hull. Tauranga has onshore hull cleaning facilities that are used by local vessels and vessels from other ports.

There is currently no formal process of notification of vessels or structures entering Tauranga Harbour with regard to their biosecurity risk (J Roberts pers. comm.). Identification of potential biosecurity risks tends to be through observations of the harbour and marina staff that are aware of the biosecurity risks from marine pests associated with hull fouling.

> *In 2008, BoPRC was alerted that two barges with Styela attached were being moved from Auckland to Tauranga. The barges were identified as a biosecurity risk in the harbour. One barge was cleaned and the other removed from Tauranga within 24 hours of its arrival (BNZ 2008).*

As a result of this incident and because of increased awareness of biosecurity risks, the BoPRC's resource consent conditions have been changed to the effect that "*any vessel entering the Bay of Plenty marine area must be free of all unwanted organisms or other harmful marine species".* However, these regulations only apply to vessels involved in consented activities.

Whakatane harbour has fewer vessel movements than Tauranga, but does operate a bed mobilisation dredging programme using a vessel that works between Whakatane and Whangamata, spending approximately 6 months in each area (P Cavanagh pers. comm.).

The absence of routine monitoring means that the movement of structures and vessels, that have significant levels of hull fouling, to the Bay of Plenty remains a very high risk to biosecurity in the region.

3.4. Aquaculture Transfers

Aquaculture activities not only provide pathways for dispersal of pests and pathogens, but also act as potential reservoirs for these organisms. Aquaculture structures provide new habitat on which pests can proliferate. High density monocultures of farmed organisms that may be immunologically compromised due to stress provide opportunities for parasites and diseases to become established.

Human-mediated movements of aquaculture stock and equipment are capable of transmitting pests and pathogens over large distances in a relatively short time-frame. Transfer of aquaculture equipment within New Zealand is believed to be responsible for the dispersal of a number of pests, including *Undaria pinnatifida* and *Didemnum vexillum* (Keeley et al 2009). More recently the potential to move pathogens associated with aquaculture stock has been highlighted by the spread of the Ostreid herpes virus. Although the transport vectors for the virus have not been clearly identified, consensus suggests that the most likely transport vector is the transfer of oyster seed between spat catching sites and on-growing areas.

Information on the movements of aquaculture stock and equipment has been collected as part of the MPI Aquaculture Readiness Project (MPI 2011a) and mapped in a GIS to illustrate the aquaculture species moved, the sources and destinations. A full report on aquaculture transport vectors is expected to be published in 2014.

Common examples of aquaculture stock transfers include:

- Transfer of mussel spat from Ninety -mile Beach in Northland to marine farms throughout New Zealand.
- Movement of oyster spat from collection sites (e.g. Kiapara harbour) to farm sites in the upper North Island.
- Movement of oyster spat from Nelson and the Marlborough sounds to Northland.
- Movement of stock to and from trout hatcheries.

MPI has provided protocols to help to reduce the risk of transfer of pests and diseases associated with aquaculture activities (www.biosecurity.govt.nz/files/pests/salt-freshwater/aquaculture-factsheet.pdf) and the three industry associations representing Mussels, Oysters and Salmon producers have also developed codes of practice aimed at minimising the environmental impacts (including biosecurity risks) from their industries.

Management of pathways to reduce the risk of infection of farm sites and/or the subsequent spread of marine pests, include:

- Procedures for domestic stock transfers (including associated transfer water) that are consistent with MPI border standards.
- Procedures for vessels and/or the transfer of equipment to minimise the risk of marine pest transport with shellfish culture pathways (e.g. Vessel antifouling, cleaning, inspections). These include not only vessels routinely employed on the farm, but also specialist vessels used for deploying moorings, harvesting, delivering feed and seed and research activities.

On-farm management practices to reduce risk to the wider environment include:

- Education and surveillance to facilitate early detection of pest species.
- Routine farm management procedures for cleaning of culture equipment (e.g. floats, lines and racks) between crops.
- Application of pest response and containment procedures where feasible.
- Farm site selection and management practices that maximize growth and condition, and minimise risks of pest infestations.

The risks outlined above are primarily aimed at open environment aquaculture (long lines or cages within the marine environment or fish stocked in pond and rivers). The risks associated with aquaculture activity vary depending on the type of activity undertaken. Risks associated with different types of aquaculture activity are reviewed below.

Despite the limited aquaculture activity in the Bay of Plenty region the area has already been subjected to significant losses through the Ostreid herpes virus. Oyster seed have historically been, and continue to be, transported to the region from spat catching sites the Kaipara harbour and Maharangi (R Yorke pers. comm.). It is likely that the virus was transferred to the region in association with this seed stock.

The offshore mussel farm trials currently underway at Opotiki have to date not shown any signs of pest species. The farm operates a policy of using only locally caught mussel spat to minimise the risk *of importing diseases and pests. However, the site remains at risk through importation of pests on service vessels.*

The Ngongotaha trout hatchery is the largest hatchery in the North Island, producing approximately 100,000 yearling trout for restocking around 12 lakes within in the region and 20 other lakes in the North Island. The hatchery uses locally collected broodstock from Lake Tarawera, that are collected on an annual basis. Basic quarantine, stock and equipment separation protocols are used within the hatchery to protect against the spread of disease. Formal protocols exist for disease detection and control. The hatchery uses spring fed water, limiting the likelihood of pest or diseases entering through the water supply. However the hatchery effluent is not treated prior to discharge. The hatchery may therefore provide pathways for transfer of freshwater pests and diseases either through discharge water or through stock transferred from the site (M Sherburn pers. comm.).

Although industry best practice and protocols are likely to be applied to aquaculture development within the Bay of Plenty there remains a very high risk that pests and diseases may be imported into the region in association with aquaculture equipment or stock.

3.5. Commercial Fishing Vessels

The biosecurity risks from commercial fishing vessels will largely depend on the nature and extent of fouling on these vessels. The hulls of locally owned fishing vessels are generally cleaned annually. The New Zealand Fishing Industry Association (NZFIA) has adopted a voluntary code of practice for the chartering of foreign-owned or foreign-sourced fishing vessels, to reduce the risk of heavily fouled craft entering New Zealand waters. Under the Code, New Zealand fishing companies chartering a foreign vessel were obliged to obtain a guarantee from the vessel owner/operator that the hull of the vessel was “substantially free from plant or animal growth” on entry to New Zealand (NZFIA 1997).

While yearly hull cleaning and anti-fouling of vessels is likely to result in some risk reduction in certain circumstances (e.g. where a slow-growing species or a microscopic fouling stage is present) it may be insufficient to prevent the spread of fast growing marine pests (Dodgshun et al 2007).

Eight foreign chartered fishing vessels were surveyed in the MAF commissioned research on vessel bio-fouling (Piola and Conwell . 2010). Among these vessels, the time since last dry-docking varied from 3 weeks to over 3 years. The average time since last dry-dock (and application of anti-fouling paint) was 420 ± 105 days (mean ± SE). All vessels surveyed had steel hulls, and high pressure water-blasting in dry-dock was the most common hull treatment prior to anti-fouling.

The potential to transfer pests attached to fishing gear has received little attention worldwide. An outbreak of the abalone ganglioneuritis virus in Australia prompted abalone fishermen to adopt more rigorous cleaning regimes for their equipment, but additional cleaning activities were not extended to other inshore fisheries. Potentially, viable fragments of non-native species can be transferred between regions on fishing gear such as nets and pots. Herborg et al 2008, consider fishing vessels as a likely vector for the transfer of Didemnum for nearshore to offshore habitat.

However, in New Zealand, fishing nets and gear tends to be either used offshore over a wide area or locally inshore, suggesting that likelihood of transfer of pests between the two environments may in reality be quite low.

Bait used for crayfish pots and long lines may also pose a biosecurity risk if it is imported from other countries or other regions of NZ with specific pest or disease risks. For example, Jones et al (1997) indicated that an outbreak of pilchard herpes virus in Australia in the 1990s may have been linked to import of frozen pilchards as tuna feed. In New Zealand the use of non-local bait is likely to be largely offshore for longline vessels and most bait is frozen prior to use, significantly reducing any biosecurity risks from pest species. However, freezing is less effective at killing pathogens and as such the use of frozen baits is not without risk.

3.5.1. Marine Fishing

Tauranga harbour is home to approximately 20 fishing boats and a similar number of charter fishing vessels (J Roberts pers. comm.). Whakatane Harbour has a small fleet of fishing vessels (1 surface long liner, 1 set netter and 1 cray boat) (P Cavanagh pers. comm.) and approximately 25 charter vessels.

Many of the fishing boats operate over a wide area of New Zealand's EEC. The surface longline vessels and a number of the charter vessel regularly fish outside of the Bay of Plenty region.

Despite the significant number of commercial fishing vessels within the region, industry association guidelines in relation to hull fouling and the localised nature (inshore or offshore) of commercial fishing activity indicates that commercial fishing can be assessed as posing a relatively low risk to biosecurity in the Bay of Plenty.

3.5.2. Freshwater Fishing

Commercial fishing in freshwater is confined to eel capture, which seldom uses boats. However, this activity poses biosecurity risks through the transfer of plant and algal material attached to eel nets and other fishing equipment. The fishery is accessed by fishers from outside the Bay of Plenty region as well as local fishermen. The eel fishing industry body (Eel Enhancement Company Ltd) is aware of biosecurity risk in particular transfer of pest flora or fauna between catchments, and encourages thorough cleaning of equipment before transfer between sites (J Jameson pers. comm.).

There is an active, but small (5 tonnes per year) (Beentjes 2011), freshwater eel fishery in the Bay of Plenty region. A proportion of the fishermen accessing this fishery also fish outside of the region and despite industry awareness of the potential for pest transfer there remains a moderate risk of pest transfer attached to eel fishing equipment.

3.6. Aquariums

A wide range of plant and animal species are imported and bred for use in home and commercial aquariums each year. Many of these are not native to New Zealand and some may carry diseases that could impact on the environment and aquaculture activities. Whilst many ornamental species derive from tropical countries, and may not survive in New Zealand's more temperate water, some species, particularly those reared for ornamental ponds, are capable of surviving in the wild. A number of instances where escapes or releases from aquariums have led to environmental impacts have been recorded in New Zealand. For example Koi carp (*Cyprinus carpio*) were introduced to New Zealand as an ornamental fish, but are now present throughout the lower Waikato River.

MPI considers that there may be significant risks of importing invasive pest species and diseases alongside other aquarium species. Consequently MPI is currently completing a biosecurity risk assessment for aquarium and aquatic plant breeders in New Zealand.

In 2011/12 the Bay of Plenty Regional Council undertook surveillance of 1721 properties. 138 (12%) properties had an ornamental pond present. The inspections revealed that 30% of the ponds found contained species known to be pests, however, with one exception, the pests found were already known to be present in the adjoining water bodies. The exception was one discovery of Senegal tea (an exclusion and eradication pest), which has subsequently been controlled (BoPRC 2012b).

As evidenced by the BoPRC study, the transfer of organisms from private aquaria to ponds and potentially to the sea cannot be ignored. This vector must therefore be considered to be significant risk in terms of introducing non-native plants and diseases.

3.7. Recreational Vessels (Tourism and Fishing)

Recreational vessels comprise both those that are moored for long periods of time and those that are trailered for use in freshwater and the sea. Recreational vessels include power boats, yachts, dinghies, kayaks and windsurfers.

Piola and Forrest (2007) considered that recreational vessels moored in-water are a particular biosecurity concern because they:

- Remain idle for long periods (Hewitt et al 2009; 2011) and can become heavily infected by pest species, especially fouling organisms.
- Are often slow moving, meaning associated fouling assemblages tend to survive vessel passage rather than being dislodged or otherwise affected by shear.
- Are numerous, for example, there are greater than 10,000 marina berths in New Zealand (Dodgshun et al 2007).
- Often make direct visits to high value areas such as marine reserves and aquaculture sites.

- Carry equipment such as fishing tackle, diving equipment and water skis that may be used in multiple areas.
- Are largely unmanaged for biosecurity risk at present (Forrest 2007).

As a result of the above risk factors, movements of recreational vessels are often implicated in the national and regional spread of marine pests (Dodgshun et al 2007).

Trailered recreational vessels used in fresh water pose a significant risk as transport vectors for pests (Dodgshun et al 2007). Some invasive freshwater species can withstand periods of time out of water and are therefore able to hitchhike between boating locations on trailers and gear associated with pleasure craft. Transfer of freshwater pests such as didymo and hornwort on trailered boats or on fishing equipment associated with both boats and angling is a particular area of concern.

Trailered vessels used in the marine environment may pose less of a biosecurity risk, as they are often washed with fresh water and dried between immersions, and tend to fish within a limited range of coastal areas. However, they still pose a significant risk in terms of transfer of pest seaweed and algae. Environment Bay of Plenty (EBop 2008) considered that "*boat trailers are the biggest spreader of marine weeds. Boat wash down areas are only about 70% effective, as they only remove the obvious organisms and not the plant fragments that can exist for many weeks/months in damp crevices*".

Recreational boating activity within the Bay of Plenty region is predominantly based on trailered vessels, with many of these coming from outside of the region (BoPRC 2012a). Approximately 20% of households in the Tauranga/Western Bay of Plenty Census area have at least one boat (Maritime Safety Authority of New Zealand, 1999). This equates to 10,400 boats in 2001 and projected to increase to 15,400 boats by 2021. It is estimated that there are well in excess of 200 boats per day launched from the 25 boat ramps in and around Tauranga (EBoP 2008).

There is also a significant level of moored vessel activity within the region, with nearly 400 swing moorings and 1061 marina berths in Tauranga Harbour.

Highlighting the risk of pest transfer on moored recreational vessels, the following press release was put out by BoPRC on Wednesday, 20 November 2013:

> *"A boat infested with the unwanted marine pest Styela clava, also known as clubbed tunicate sea squirt, has been found berthed in Tauranga Harbour.*
>
> *Bay of Plenty Regional Council Natural Resource Operations Manager Warwick Murray said that it's the second boat with Styela clava on its hull that has been found in Tauranga Harbour in the last month.*
>
> *"The first boat was moored in Pilot Bay and this latest one was berthed at Bridge Marina. Both boats have been recently brought here from Auckland, without prior cleaning of their hulls."*
>
> *Mr Murray said that recreational boats are not the only way that marine pests are spread, but they are high risk."*

Probably because of its proximity to inshore fishing grounds, Whakatane provides access for up to 15,000 pleasure vessel movements annually. Many of these are trailered vessels that are locally based or come from Rotorua. Whakatane only offers mooring for commercial vessels and has berths in one small private marina for recreational craft. Due to the difficult river bar at Whakatane there is little yachting activity and the marina rarely hosts visiting yachts from Auckland. At least one charter yacht from the marina regularly makes trips out to the Pacific Islands (P Cavanagh pers. comm.).

There is a high level of recreational boating (both freshwater and marine) activity in the Bay of Plenty. Recreational boating is unregulated in terms of biosecurity and boats may regularly travel to areas with known biosecurity risks. There is a high risk of pest transfers via this vector particularly in terms of the movements of trailered boats and associated equipment between freshwater lakes

The large number of marina berths and swing moorings in Tauranga harbour provide opportunities for fouled vessels from other ports to move to Tauranga. Consequently, there is a very high risk of pest introductions via this vector.

The Ngongotaha trout hatchery runs open days that include opportunities for children to fish in the hatchery ponds. However, fishing tackle is supplied on site and the risk of pest or disease transfers from other areas is therefore low.

3.8. Research Activities

Research activities pose a potential biosecurity risk both through the movement of aquaculture species and the movement of potentially contaminated research equipment between areas in New Zealand.

Aquaculture species are often moved between areas in New Zealand for research work. For example, in recent years NIWA have moved kingfish, salmon and Hapuka between Wellington, Ruakaka (Northland) and the Marlborough Sounds to undertake culture trials. Sea cucumber juveniles have been moved between Wellington, the Marlborough Sounds and The Bay of Plenty Polytechnic.

Research organisations frequently undertake studies in multiple regions, necessitating the movement of research equipment between field sites. Whilst there are not currently any reported incidences of pest or diseases transported on research equipment in New Zealand the potential for transfer via this this vector cannot be ruled out.

Within the Bay of Plenty region, there are currently three key research activities related to aquaculture.

The Bay of Plenty Polytechnic houses a seawater system to undertake aquaculture research projects on a range of fish and invertebrate species. The system does not have a direct connection to the sea, and so the potential for escape of pests or diseases from the system is very low.

The offshore mussel farm at Opotiki is still in its developmental stages and as such is subject to research activities. These are largely undertaken by the Cawthron Institute, Nelson. Whilst Cawthron scientists are aware of biosecurity protocols for cleaning equipment before transferring to another site, there remains some potential for transfer of pest or diseases via this mechanism, although it should be classified as very low.

The University of Waikato operates a marine research station at Sulphur Point, Tauranga. The marine station is a collaboration between the University of Waikato and its tertiary partners Bay of Plenty Polytechnic, Te Whare Wananga o Awanuiarangi, Bay of Plenty Regional Council, Port of Tauranga, Smart Growth and Priority One. The station links the Bay of Plenty into marine 'hot spots' in the rest of New Zealand and internationally, positioning the region as a major centre for marine-based research to support economic development, not only for aquaculture, but also for pharmaceutical and agrichemical innovations owing to the high level of marine biodiversity in the Bay of Plenty. Although the station has direct connection to the surrounding marine environment, its focus on research using local species indicates that the biosecurity risk from this activity can be regarded as low.

3.9. Natural Dispersal

Whilst human mediated movements of stock and equipment can occur over large distances, the movement of pests and pathogens by passive means such as tides, currents and river flows occur over relatively small spatial scales. Long distance dispersal via these mechanisms is unlikely for many species due to the time period that pathogens remain infectious and pests remain viable and buoyant (MPI 2011a).

An organism's dispersal potential is influenced by environmental factors that regulate its metabolic growth and survival. More complex organisms (such as protozoan parasites, parasitic worms and parasitic crustacea) often have a free-living (perhaps actively swimming) stage that can remain in the water-column for hours to days and potentially travel significant distances depending on currents driven by wind, waves and tides. The location and extent of pest and disease dispersal will therefore vary day to day, influenced by factors such as wind direction, strength of stratification and tidal currents (Zeldis et al 2011).

Natural dispersal over larger distances requires intermediary steps, and is often called "stepping stone dispersal". Here a pest or pathogen moves through a suitable environment in a series of short steps, settling, growing and reproducing in one area before currents carry its offspring a short distance to the next area. The absence of suitable stepping stones limits the distribution of species by this method. Distribution by natural dispersal will also be limited by the environmental requirements (e.g. thermal tolerance) of the species concerned.

The MPI Aquaculture Readiness project (MPI 2011a) did not consider natural dispersal for the Bay of Plenty region. However, mapping for the Firth of Thames and Coromandel indicated relatively small 24hr dispersal zones, that did not extend into the Bay of Plenty region (Figure 2). Whilst it isn't possible to confidently indicate the potential time frame for natural dispersal of invasive species, the Aquaculture Readiness models and natural indicators (such as dispersal of Styela), suggests that natural dispersal from the Hauraki Gulf and the Coromandel to the Bay of Plenty is unlikely to occur over a short time frame. There is therefore a low risk of incursions into the Bay of Plenty by natural dispersal over a short time frame.

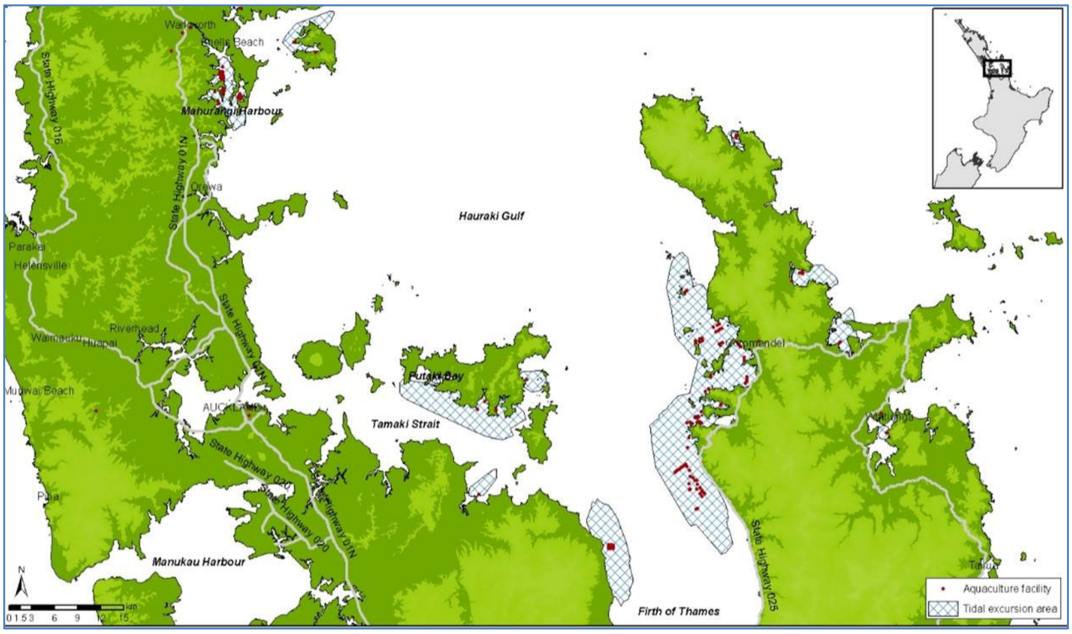

Figure 2. Map indicating 24 hour dispersal zones from aquaculture operations in the Firth of Thames and the Coromandel (MPI 2011a).

Table 4. Summary of the potential for a range of transport vectors to transfer pests and pathogens to the Bay of Plenty.

Vector	Notes	Risk of transfer
International Shipping	Tauranga has a significant international traffic flow. Invasive species recorded within the port.	Moderate / **High** (New and existing species)
Domestic Shipping	Potential transport in ballast water and on anchors.	**High**
Moveable structures	Potential for barges and other structures to be moved from infested areas to Tauranga.	**Very High**
Aquaculture Transfers	Potential movement of stock to the area. Particularly oysters.	**Very High**
Commercial Fishing	Sea - hull fouling or attached to equipment Freshwater – weed fragments attached to nets	Low Moderate
Aquariums	Little aquarium activity within the region.	Low/Moderate
Recreational Vessels	Significant amounts of recreational activity, risks from trailers and from relocation of fouled yachts.	**Very High**
Research	Limited research activity with good biosecurity protocols in place.	Low
Natural Dispersal	Significant spacing between existing farms and farms in other regions	Low

4. Biosecurity Risks Associated with Aquaculture Technologies

There are many technologies used for aquaculture production in New Zealand. Production technologies are developed and adapted to be appropriate for both the species cultured and the local environment. Consequently similar species may be subject to different culture techniques in different areas.

The biosecurity risk associated with a given aquaculture technology is a function of a range of variables that include its environment, the culture equipment used and source of stock. In this section we shall review the current aquaculture technologies likely to be employed in the Bay of Plenty with regard to their potential to be impacted by biosecurity incursions.

4.1. Mussel Farming

Mussel farming is New Zealand's largest aquaculture industry occurring in coastal bays throughout the country.

Mussels are cultured on long line systems where the mussels grow on a series of dropper ropes hanging from a sturdy 'backbone' rope that is held up by a row of buoys. These systems have traditionally been established within sheltered bays. However, a number of offshore developments are being trialled to test the potential for mussels to be grown in more exposed areas. An offshore mussel farm development is currently being trialled off Opotiki.

The location of mussel farms in the coastal environment makes it extremely difficult to effectively protect them from water borne pests or pathogens established in the environment. The structures and materials associated with mussel farms provide numerous surfaces for colonisation by fouling organisms. These surfaces are often free of native biota when first deployed and are therefore often colonised by opportunistic fouling organisms. Marine farms do not tend to use antifouling compounds and often go many months without being cleaned, allowing populations of fouling organisms to become established.

4.1.1. Pests

A number of occurrences of pest infestations of mussel farms have been recorded in New Zealand. Most notably these include fouling by Styela, Didemnum, and Undaria. The effects of these infestations can be summarised as:

- Reduced growth, condition and health of stocks
- Increased handling associated with pest intervention leading to increased risk of stock loss/drop-offs, increased stress on stock and increased operational costs.
- Increased waste production (mortalities), leading to land disposal and associated environmental effects, including disease transfer risk.

4.1.2. Diseases

The New Zealand Mussel farming industry has to date been free of disease outbreaks. However, the heavy reliance on Kaitia spat that is transported around much of New Zealand makes the industry particularly vulnerable should a mussel disease causing agent become established in New Zealand.

4.2. Sea Cage Farming of Finfish

Marine farming of finfish in New Zealand is currently limited to Salmon culture. Salmon farms have been established in the Marlborough sounds, Akaroa and Stewart Island.

Cage fish farms rear fish in large net pens suspended from either rafts or float rings. They are generally sited in sheltered bays that have good water flow through them. The cages are stocked with juvenile fish that have been reared in land based hatcheries.

As with mussel farms, the location of fish farms in the coastal environment prevents any effective control of water borne pests or pathogens. The large area of relatively fine netting associated with the cages provides a large surface for colonisation by fouling organisms. These surfaces are free of native biota when first deployed and are therefore often colonised by opportunistic fouling organisms. An overview of marine biosecurity risks related to marine finfish aquaculture developments is provided by Forrest et al (2011).

4.2.1. Pests

As with mussel farms, finfish farms have suffered from fouling by Styela, Didemnum and Undaria. The effects of these infestations can be summarised as:

- Increased drag on sea-cage infrastructure, deforming cages and posing risks from gear failure and escapes.
- Clogging of nets causing reduced water exchange inside cages. This resulting in poor oxygen exchange (especially in summer) and a reduction in waste removal.
- Pests can act as potential intermediate hosts for pathogens and parasites.
- Fouling attracts wild fish species that could become parasite/pathogen vectors or intermediate hosts.
- Nets fouled with pest species may have to be cleaned in secure facilities onshore, precluding the use of more cost effective *in-situ* net cleaning techniques.

4.2.2. Diseases

Because of its isolation, New Zealand is uniquely free of all of the serious pathogenic diseases that can affect salmon. However, the low thermal tolerance of salmon means that it is highly unlikely to be farmed in the warm waters of the Bay of Plenty.

A number of parasites and diseases have already been detected in farm trials for kingfish and Hapuka. Sea cage aquaculture developments using these species are likely to be subject to disease and parasite infections that will impact on production through increased costs to vaccinate fish, treatment of disease and stock losses.

4.3. Oyster Farming

Pacific oysters are predominantly grown on sticks, trays and netting bags on intertidal farms. Farm site selection is critical and most are built in shallow, sheltered waters between the high and low tide marks to optimise growing conditions.

Oyster spat is often collected from the wild. Farmers catch oyster spat by placing treated sticks in the sea in areas known to have large natural spat production. Oyster spat settle onto the sticks which are then moved to on-growing sites. For on-growing the sticks are attached to racks built so that the oysters sit just above water level at low tide. Oyster spat can be also be supplied from commercial hatcheries as unattached seed (single seed) and grown in mesh bags placed on the racks or strung from wires in the intertidal zone.

Some farmers produce Pacific oysters in deeper water using trays strung beneath the surface, on longlines supported by plastic floats. These are similar to the longlines used for mussel farming. Farmers with both intertidal and subtidal sites will transfer oysters between farms to optimise the condition of the oysters at harvesting.

Three intertidal oyster farm leases are present in Ohiwa Harbour. Currently, all three leases are farmed by Ohiwa Oyster Farm. On these farms oysters are grown on sticks and in trays on intertidal racks.

4.3.1. Pests

The association of pest organisms on oyster farm structures in New Zealand has never been explicitly evaluated, although there are a number of examples where pest organisms have been recorded at high densities on oyster farms. These include Styela, Eudistoma, Didemnum and Undaria. The effects of these infestations can be summarised as

- Reduced growth, condition and health of stocks.
- Increased handling associated with pest intervention leads to increased risk of stock loss, increased stress on stock and increased operational costs.
- Increased waste production (mortalities), leading to land disposal and associated environmental effects, including disease transfer risk.

Fouling on the oyster farm at Ohiwa is predominantly by native species such as mussels and sea squirts. This fouling can be heavy at times and necessitates the operator taking equipment ashore to clean (R Yorke pers. comm.).

4.3.2. Diseases

Diggles et al (2002) report several parasites or pathogens associated with Pacific oysters, most of which are globally ubiquitous and appear to be a risk to oyster production. These include Ostreid herpes virus, and various species of flatworm and mud-worm.

The routine movement of oyster spat between catching areas and on-growing areas, and the movement of part grown oysters between intertidal and sub tidal growing areas poses a significant risk of disease transfer.

4.4. Land Based Marine Farms

Land based marine farms have been trialled in New Zealand for Paua and kingfish. Currently there are less than 10 operational Paua farms throughout New Zealand, with only one farm operating at a significant scale. Onshore farms normally use tank culture systems for stock rearing, but recently there has also been interest in using marine ponds for cultivation of sea cucumbers.

Land based marine farms offer the opportunity to isolate farmed stocks from the surrounding environment through filtration of intake and waste water. The degree of isolation is entirely dependent on the level of filtration and the biosecurity protocols surrounding the importation of stock and feed. Tank systems that use a single pass of water through the farm (flow through) require significant volumes of water to be pumped on a daily basis and therefore fine filtration of this water is not cost effective. Systems that use recirculation technology reuse the water within the system many times, and therefore exchange a much smaller volume of water each day. These systems are more likely to be able to effectively clean both intake and waste water.

Coastal pond systems that rely on tidal water exchanges and have little direct filtration are exposed to a higher level of biosecurity risk than enclosed tank based systems.

There are currently no land based marine aquaculture systems within the Bay of Plenty region. In 2005 Ngati Ranganui investigated the potential of a land based finfish farm near Tauranga, but decided that such as development was not feasible at that time (B Kawe pers. comm.). The Whakatohea Maori Trust Board is currently investigating the feasibility of pond culture of sea cucumbers near Opotiki.

4.4.1. Pests

Most pest organisms are readily filtered out of intake water and there have to date been no recorded incidences of invasive biofouling or pest species affecting land based marine farms in New Zealand.

4.4.2. Diseases

The occurrence of diseases and parasites in land based systems is a significant concern for system operators. Large volumes of stock confined within tanks increase the risk that parasites and diseases will quickly proliferate. Several parasite infections have been recorded in research scale land based systems in New Zealand, including haplosporideans, ciliates and monogeneans (Anderson et al 2009) and there is a significant risk that these parasites will occur in commercial operations causing losses of stock, reduced growth rates and increased operational costs through implementation of treatment regimes.

4.5. Freshwater Culture Systems

A significant number of land based freshwater aquaculture systems exist in New Zealand producing a range of species including trout fingerlings, salmon, freshwater crayfish (Kōura), goldfish, prawns and ornamental aquatic plants. The majority of these are based on pond systems, although tank culture (various eel culture trials) and cage culture (salmon in canals from power stations) production methods are also used.

Biosecurity risks for freshwater tank culture can be considered as similar to those for land based marine farms.

Biosecurity risks associated with freshwater production are dependent on a number of factors such as the source of water (spring, bore or river/stream), source of stock and local pests and diseases. Probably the freshwater culture technique with the greatest exposure to biosecurity risks is stream fed pond culture, as effectively filtering stream water is difficult and costly.

Pond pests and predators not only eat fish and/or compete for food and other resources, but can also spread and transmit diseases. Often the extent of an impact by a pest or predator is not observed until a significant proportion of fish are already affected. Invertebrates such as oligochaete worms, snails, and insect larvae, and vertebrates such as aquatic birds, amphibians, and unwanted fish species are all potential health and biosecurity risks. Animals such as cattle which come in contact with, or enter, ponds can also spread disease. Birds can spread disease-causing organisms (bacteria, viruses, parasites, fungi) mechanically, on their skin or in their faeces, and can often be a necessary part of a parasite life-cycle.

There are currently no commercial freshwater pond culture systems in the Bay of Plenty Region although pond culture and tank culture systems are used at the Ngongotaha trout hatchery for rearing trout for release.

4.5.1. Pests

Systems that rely on water supply from streams or rivers are at particular risk from freshwater pests, including pest fish and invertebrate species and aquatic weeds. However, there are few recorded instances where pests have caused significant impacts on pond production other than smothering by aquatic weeds. Normal best practice for pond farms includes routine draining and drying of ponds every 2-3 years. This generally removes pest organisms from the ponds. Infestations of aquatic weeds are normally removed during routine pond maintenance operations, but significant infestations can cause additional maintenance costs for farmers.

4.5.2. Diseases

New Zealand has a relatively short list of potential diseases for freshwater fish that may be commercially cultured.

The salmonid species commercially cultured in New Zealand have low susceptibility to whirling disease. The disease causes mortalities in young fish and affects the ability to export fish from infected sites (Anderson 1996).

Furunculosis in salmonids is a significant risk to aquaculture and is caused by the bacterium *Aeromonas salmonicida* ssp. *Salmonicida* that causes ulceration and can lead to mortality.

Up until 2011, no variants of *A. salmonicida* had been recorded from New Zealand (Diggles et al 2002). However, in the spring of 2011 wild lampreys were reported with haemorrhagic external lesions in several river systems in Southland. Testing by MAF Biosecurity confirmed that atypical strains of *A. salmonicida* were associated with the lesions. Subsequent testing found that a different Aeromonas like bacterium common in New Zealand water also infected a trout sampled from the Macraes hatchery in Otago in the spring of 2011. Therefore, to date, there remains no evidence of *Aeromonas salmonicida* ssp. *Salmonicida* in New Zealand (MPI 2011b).

A large number of parasites have been recorded in association with wild eels in New Zealand (Hine 1978) and parasite and disease outbreaks have been linked to failures in early attempts to farm eels. However, these outbreaks were probably a direct result of poor hygiene and inadequate rearing technology.

White tail disease affects Koura causing withering and mortality in farmed and wild stocks. White tail disease has not been recorded in the North Island (Quilter 1976).

Disease causing organisms are not readily removed by coarse filtration systems that treat water supplied to ponds by streams and rivers. Pond systems are therefore highly vulnerable to disease causing agents, particularly at times of hot weather when stocks may be stressed and therefore more susceptible to contracting diseases.

5. Risk Analysis

Risk is the likelihood that an adverse event will occur, and the likely magnitude of that event's consequences. In terms of biosecurity risks to aquaculture, that is the likelihood that organisms are transferred to a new location, and the scale of any subsequent adverse impacts. Whilst pathways can be highly complex and individual events can cause unexpected outcomes, generic risk factors can be identified for key pathways and operations. All else being equal, risk tends to increase where (MAF 2010):

- Species associated with significant adverse pest impacts are being transferred.
- Typical transfer distances are large, which increases the chance that organisms will be moved beyond their present range.
- Typical transfer times are short, which increases the chance that organisms will survive the transfer.
- Frequency of transfer events is high.
- Volume of risk items moved per typical transfer is high.
- The time that risk item is in the source environment is high, which increases the chance that hitchhiker organisms become entrained.
- An entire ecosystem is being transferred (e.g. biofouled hull).
- Similarity between source and receiving environments is high, which increases the chance of successful survival and establishment.
- Small organisms are typically transferred, which makes detection more difficult.
- Organisms are reliant on human mediated transfer, having limited capacity for range expansion via natural modes of spread.
- Established pest populations exist in numerous source environments, which increases the rate at which those organisms are able to utilise transfer pathways.
- People are motivated to deliberately transfer organisms.

The potential risks associated with biosecurity events impacting on aquaculture development in the Bay of Plenty region were analysed using a risk matrix. Risk is determined by combining the likelihood of an event (considering the factors above) and its consequences (Table 5). This combination provides an assessment of the risk level for a given event (Table 6).

The analysis has been undertaken for existing pest and pathogens and potential new pathogen incursions in relation to the key aquaculture activities that may be expected to occur within the region (Tables 7 and 8). This analysis assumes that existing biosecurity protocols remain in place.

Table 5. Definitions of Likelihood and consequence used in the risk analysis

Likelihood	
Highly unlikely	Not present in New Zealand and unlikely to be imported
Unlikely	Present in different environments, or not present in New Zealand but would survive if introduced
Possible	Present in New Zealand but not in BoP region. Spread can be managed by simple biosecurity protocols
Likely	Present in the environment in surrounding regions
Almost Certain	Present in BoP region.
Consequence	
Insignificant	Will not impact on aquaculture operations
Minor	Will have a minor impact that can be easily managed with little additional cost to producers.
Moderate	Will impart an economic cost on production that can be managed
Major	Will cause significant stock losses, operational costs or export restrictions that may cause aquaculture businesses to close

Table 6. Example risk matrix. Letters represent risk level for a given consequence–likelihood combination: N = negligible, L = low, M = moderate, H = high, E = extreme.

Likelihood	**Consequence**			
	Insignificant	Minor	Moderate	Major
Highly unlikely	N	L	L	M
Unlikely	N	L	M	H
Possible	N	L	M	H
Likely	N	M	H	E
Almost Certain	N	M	E	E

5.1. Mussel Culture

The absence of suitably sheltered bays means that mussel farming developments within the Bay of Plenty will be restricted to offshore environments. In the initial stages of development the farms are likely to be geographically isolated from each other and the primary source of pest or disease infection is likely to be through human mediated vectors. However, if a significant number of farms are developed in the region their geographical isolation will be reduced, increasing the potential for pests and pathogens to move between farms using natural dispersion. The intention of the Opotiki mussel farm to use only seed collected locally will reduce the risk of importing pests and diseases from other areas. However, this may provide limited protection in the long term if other mussel farming developments in the region opt to import seed. Given the prevalence of a range of fouling organisms in the Bay of Plenty and surrounding regions it seems likely that the farm will become infested with some or all of these species in the short to medium term.

Infestation of the farms by fouling organisms is likely to result in moderate to major increases in operational costs through cleaning and associated reduced growth and stock losses.

5.2. Oyster Culture

The limited number of suitable sheltered bays and estuaries within the region is likely to limit the expansion of intertidal oyster farms. The Regional plan also limits potential development of oyster farms by prohibiting structures in permanently navigable waters. Permanently navigable harbour waters are defined as: '*harbour or estuary that is covered by water at the lowest astronomical tide, but excluding: the open coast, the Port Zone, the Harbour Development Zone and the Coastal Habitat Preservation Zone*. Aquaculture structures (amongst other things) are also prohibited in the Coastal Habitat Preservation Zone.

The presence of Ostreid herpes virus in the region serves to highlight the potential for such diseases to move between farms and regions. The stock losses caused through the Ostreid herpes virus outbreak had a major impact on oyster production in New Zealand and in the Bay of Plenty. Farmers are learning to manage infected stock to reduce mortalities, and research is underway to breed oyster strains that are resistant to the virus. However, the disease is likely to continue to have major consequences for the industry in the short to medium term.

Removal of fouling organisms from intertidal oyster farms is part of the normal management practice for farmers. Infestations by pest species, therefore, rarely cause more than a moderate impact on production.

There is also potential to farm oysters on the offshore mussel farm sites, in which case they would be subject to similar fouling pest and disease risks as mussels.

5.3. Marine Finfish in Sea Cages

As with mussel farms, there are no sheltered inshore locations suited to cage fish farming in the Bay of Plenty. Any development of sea cage fish farms will therefore of necessity be offshore. Technologies for offshore aquaculture of finfish are being developed worldwide, but this industry is still very much in its infancy, and considerable technical hurdles remain to be overcome in terms of both establishing infrastructure and operational logistics. It is highly unlikely that offshore fish farms will be established in New Zealand in the short to medium term.

Candidate species for offshore marine farms in the Bay of Plenty would currently be restricted to kingfish and Hapuka, as water temperatures in the region exceed the thermal tolerance of salmon. Parasites of both kingfish and Hapuka are endemic in New Zealand's coastal environment and it is therefore almost certain that these would occur on farms and have to be controlled though treatment and stock management programmes. These programmes would impose major additional costs on production.

Sea cages established in the region would be subject to marine fouling. The presence of pest fouling species is likely to impose a moderate amount of additional costs in terms of maintaining cage structures and cleaning nets.

5.4. Marine Finfish Onshore

The development of onshore fish farms in New Zealand will require assessment and control of biosecurity risk in order to obtain RMA consent to develop the farm. For flow-through systems this is likely to focus on preventing the spread of pests and escape of fish. Such systems remain vulnerable to infections from water borne diseases and parasites and it is possible that fish reared onshore will become infected with common pests or parasites causing moderate or major impacts on production, depending on the level of infection and treatment options. .

Current investigations into onshore fish farming in New Zealand are focussing more on the use of recirculation systems that allow a greater degree of treatment of the intake and outlet water in order to reduce biosecurity risks. It is unlikely that biosecurity incursions of pest organisms within the Bay of Plenty region would present a significant risk to these operations.

5.5. Sea Cucumbers and Geoducks

The farming of sea cucumber and geoducks in New Zealand is still firmly in the research stage of development. Culture methods for these species have yet to be clearly defined, but both species are likely to be cultured on the sea bed below mussel lines or in ponds. Organisms cultured on the sea bed tend to be less prone to fouling than those reared in suspended culture. This is due to the tendency for sediments to smother and abrade fouling organisms.

The incursion of the Asian paddle crab into the region may pose a risk to development as it is likely to prey on juveniles of geoducks and sea cucumbers if they are unprotected on the sea bed.

It is possible that populations of Asian date mussels may cause the seabed to be modified, making it unsuitable for sea cucumber or geoduck culture.

No infectious diseases have been reported as attacking juvenile geoducks or sea cucumbers in the wild in New Zealand. Overseas a number of disease causing organisms have been identified in both geoducks (Bower and Blackbourn 2003) and sea cucumbers (Wang et al 2003). Whilst many of the diseases identified for both groups are related to common bacterial infections, some result from parasites. There is therefore a risk that parasites of these species may be transported to New Zealand.

5.6. Eels

Eel culture is based on on-growing glass eels captured as they return from the sea and enter rivers. In New Zealand it is currently illegal to possess eels weighing less than 220 g except under a special permit. Commercial access to glass eels to develop a farming industry will require legislative change.

Overseas, farming technologies for eels consist of both low density pond culture and high density culture in recirculation systems. Commercial development of eel culture in New Zealand is likely to focus on the use of recirculation technologies. These technologies are well suited to eel culture and have been tested in many countries worldwide. As with recirculation systems for farming marine species, the ability to isolate these systems from the surrounding environment substantially reduces any risk from invasive pests, parasites and diseases. However, the reliance on wild caught juveniles poses a risk of introducing disease with new stock.

The potential for invasive weeds and algae to block intake systems is also a risk to tank based freshwater aquaculture, especially if intakes are from rivers or streams. Maintenance schedules to clear intakes and prevent blockages would add a moderate amount to operational costs for farms.

The use of ponds to culture eels carries a significantly higher risk of infection from diseases through potential incursions by wild eels. Pond systems are also more likely to suffer from fouling from aquatic weeds and algae than tank based systems. Infections and fouling would lead to increased operational costs and could result in major economic impacts from stock losses.

5.7. Trout

Trout farming is currently prohibited in New Zealand. Opponents of trout farming point to the risks associated with introducing and spreading disease from farmed populations to the wild stocks that underpin a large recreational fishery. It is unlikely that commercial trout farming will be permitted in the short term.

However, New Zealand currently has 6 trout hatcheries that are run by Fish and Game regional offices (5) or the department of Conservation (DoC) (1). The hatcheries serve to provide juvenile trout to stock into rivers and lakes within key regions. The key biosecurity risk associated with trout hatcheries lies in relation to the use of wild broodstock. The risk that a disease associated with wild broodstock may be amplified in the hatchery reared stock and then spread to the numerous rivers and lakes that are restocked from the hatchery cannot be ignored.

Trout hatcheries, and trout farms (should they be developed) use both tanks and ponds for on-growing juvenile fish. Overseas trout are also grown in recirculation systems and in sea cages. It is possible that should trout farming be developed in New Zealand it is likely that this range of technologies, will also be employed here.

Biosecurity risks to trout farms and hatcheries would therefore include; fouling of intakes by invasive weeds and algae and the potential for the introduction of pests and disease from wild stocks.

5.8. Kōura (Freshwater Crayfish)

There are two species of Kōura in New Zealand, both belonging to the family Parastacidae. *Paranephrops planifrons* is found in the North Island and in the northwest of the South Island and *Paranephrops zealandicus* is distributed along the eastern side of the South Island and on Stewart Island. Farming Koura was legalised in 2007. Currently there are reported to be 17 Koura farms, all in the South Island. Currently, all Kōura farms are based on pond culture techniques. Biosecurity risks to Kōura farms would therefore encompass similar risks to pond culture of eels and trout. Of particular concern is loss of juvenile Kōura to predatory eels within the culture ponds.

Table 7: Summary of biosecurity risk assessments by marine aquaculture activity

Activity	Biosecurity event	Likelihood	Consequence	Risk
Mussel Culture Offshore	Clubbed Tunicate (*Styela clava*)	Likely	Moderate	High
	Whangamata sea squirt *(Didemnum vexillum)*	Almost Certain	Moderate	Extreme
	Eudistoma elongatum (sea squirt)	Possible	Minor	Low
	Mediterranean fanworm (*Sabella spallanzanii)*	Possible	Moderate	High
	Asian paddle crab (*Charybdis japonica*)	Possible	Minor	Low
	Triangle barnacle (*Balanus trigonus*)	Likely	Moderate	High
	Undaria (*Undaria pinnatifida*)	Almost Certain	Moderate	Extreme
	New mussel disease	Unlikely	Major	High
Oyster Culture (Intertidal)	*Eudistoma elongatum* (sea squirt)	Almost Certain	Minor	Moderate
	Other fouling pest organisms (Styela, Didemnum, Undaria)	Possible	Minor	Moderate
	Asian paddle crab (*Charybdis japonica*)	Possible	Minor	Low
	Ostreid herpes virus	Almost Certain	Major	Extreme
Offshore finfish culture	Fouling pest organisms (Styela, Didemnum, Undaria, Eudistoma)	Almost Certain	Moderate	Extreme
	Parasite infections (Haplosporidosis and Monogeneans)	Almost Certain	Moderate	Extreme
	Other disease causing agents (unknown)	Possible	Major	High
Onshore finfish culture	Fouling pest organisms (Styela, Didemnum, Undaria, Eudistoma)	Unlikely	Minor	Low
	Parasite infections (Haplosporidosis and Monogeneans)	Possible	Major	High
	Other disease causing agents (unknown)	Possible	Major	High
Sea cucumber culture	Fouling pest organisms (Styela, Didemnum, Undaria, Eudistoma)	Possible	Minor	Low
	Asian Date Mussel	Possible	Moderate	High
	Asian paddle crab (*Charybdis japonica*)	Possible	Moderate	High
	Parasite and disease infections (unknown)	Possible	Major	High
Geoduck culture	Fouling pest organisms (Styela, Didemnum, Undaria, Eudistoma)	Possible	Minor	Low

	Asian Date Mussel	Possible	Major	High
	Asian paddle crab (*Charybdis japonica*)	Possible	Moderate	High
	Parasite and disease infections (unknown)	Possible	Major	High

Table 8: Summary of biosecurity risk assessments by freshwater aquaculture activity

Activity	Biosecurity event	Likelihood	Consequence	Risk
Fish culture (recirculation)	Invasive weeds and algae (blocking intakes)	Possible	Moderate	High
	Invasive weeds and algae (within the system)	Highly unlikely	Low	Low
	Native pathogens (e.g. *Myxobolus cerebralis)*	Possible	Major	High
Fish culture (ponds)	Invasive weeds and algae (blocking intakes)	Possible	Moderate	High
	Invasive weeds and algae (within the ponds)	Possible	Moderate	High
	Native pathogens (e.g. *Myxobolus cerebralis)*	Possible	Major	High
	Invasive pathogens	Highly unlikely	Major	Moderate
Kōura culture (ponds)	Invasive weeds and algae (blocking intakes)	Possible	Moderate	High
	Invasive weeds and algae (within the ponds)	Possible	Moderate	High
	Native pathogens (e.g. *Thelohania contejeani)*	Unlikely	Major	High
	Invasive pathogens	Highly unlikely	Major	Moderate

6. Mitigating Risks

Development of biosecurity risk mitigation strategies for the Bay of Plenty region is beyond the scope of this document. However, it is relevant here to mention some simple guiding principles in relation to mitigating the risks associated with pests and diseases to aquaculture.

Hewitt and Campbell (2007) point out that the prevention of a marine invasion is frequently easier than the clean up afterward. They noted that, although some eradication attempts partially controlled the pest population or wholly succeeded, the vast majority of newly discovered incursions were beyond immediate control. As a consequence, the greatest effort should be oriented towards limiting the numbers of new species crossing national or regional boundaries.

Aquaculture developments face particular risks from biosecurity incursions, which not only have a significant impact on the economics of the business, but also potentially impact on the public image of the industry. If the Bay of Plenty is to develop a significant aquaculture industry, then it is important that steps are taken to minimise the risks of new pest organisms establishing themselves in the region. Given the risks identified above, the following actions would serve to reduce the likelihood of a potentially damaging biosecurity invasion:

- Establish a programme of targeted public education (and signage) to increase awareness of the risks associated with transferring fouled vessels between regions.
- Improve linkages between marinas and harbours in neighbouring regions to alert operators to the movements of fouled vessels.
- Increase awareness amongst commercial operators, particularly those involved with moveable structures and barges, as to the risks associated with moving fouled vessels between regions.
- Increase surveillance of high risk structures/vessels, including swing moorings and barges/moveable structures.
- Increase activity of the Top of the North Marine Biosecurity Partnership to share information on biosecurity risks between regions.

In terms of aquaculture developments, it is recognised that it is much simpler to apply meaningful biosecurity measures in intensive small-scale aquaculture systems than to those in open marine environments. However, for all farms there are suitable measures and simple elements that can be applied in all areas to minimise risks of introducing and spreading pests and disease (Cefas 2009). These include:

- Identification and use of reliable sources of stock.
- Application of good management practices and industry codes of practice.
- Effective recognition of pests and diseases.
- Identification of effective measures to take in the event of biosecurity incidents.

It is incumbent on new aquaculture developments and industry bodies to develop and adhere to biosecurity management plans in order to minimise the biosecurity risks to their business, to other aquaculture businesses and the environment.

7. Conclusions

The Bay of Plenty Aquaculture Strategy proposes that a large increase in aquaculture activity in the Bay of Plenty will occur over the next 10 years. Significant effort is being placed on the development of offshore longline systems to farm mussels and other invertebrates, and these activities are likely to underpin aquaculture development in the region in the short term. Other activities, such as onshore and offshore finfish farms are more likely to be long term outcomes of aquaculture development in the region.

Regardless of species or technology, aquaculture operations situated within coastal marine and freshwater environments are susceptible to impacts from fouling and diseases that are present within the environment. Once farms are infested with pests, eradication programmes are expensive and rarely effective. Therefore, the best control measure is to prevent incursion whenever possible.

The Port of Tauranga hosts a considerable amount of international shipping each year. International shipping poses the most significant risk in terms of introducing new pests and diseases to New Zealand, and a number of invasive species have been recorded in the port. Despite changes in biosecurity standards for ships entering New Zealand waters, this transport vector remains a significant risk for introducing new organisms.

A number of indigenous, cryptogenic and non-indigenous marine and freshwater pests and diseases are already present in the Bay of Plenty, and others are present in surrounding regions. A number of these organisms have the potential to pose major risks to aquaculture either through diseases that cause significant mortalities, or through fouling that increases operational costs.

Many of the fouling pest organisms are sessile and have short lived larval phases. They therefore require human mediated transport vectors to enable colonise new areas. Identifying and controlling transport vectors that may lead to the introduction of new pests and diseases is likely to be the most effective means of protecting the developing aquaculture industry from losses due to pests and diseases.

The key transport vector risks for the Bay of Plenty appear to be:

- Movement of vessels and structures with associated hull fouling (commercial and recreational).
- Movement of aquaculture stock and equipment between regions.
- Domestic shipping movements (ballast water and anchors).
- Trailered recreational vessels operating on lakes and rivers.

Of particular concern is the absence of notification systems and routine surveillance for fouled vessels entering the Bay of Plenty from other ports, such as Auckland, that have known biosecurity risk species present.

Although there is interest in onshore development of eel and commercial trout farms, these cannot proceed without legislative changes to enable these activities. Should such legislative changes occur, it is likely that the production units would require a high level of biosecurity to prevent interaction between farmed stocks, wild eels and recreationally valuable trout stocks. The implementation of such biosecurity measures is likely to be a condition for any resource consent issued for freshwater aquaculture developments.

Biosecurity incursions present risks not only to aquaculture, but to a whole range of social activities and environmental values. The aquaculture industry has strong production and marketing incentives to minimise the risks to themselves and to the environment from biosecurity incursions. The presence of pests and diseases not only reduces profitability, but also impacts on the social license for marine farms to operate in public spaces.

Whilst it is important that the aquaculture industry develops and adheres to biosecurity management plans, they only address one small part of the risk profile. Industry activities must therefore be in concert with other marine users in order to effectively minimise the risks from all transport vectors that can introduce pests to the region.

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10. Appendix 1. Synopsis of Diseases, Parasites and Pests Identified in New Zealand Cultured Organisms

A summary of diseases, parasites (condensed from Diggles et al 2002), and pests associated with NZ aquaculture and the potential for these to occur in farmed stocks in the Bay of Plenty subject to good husbandry, and their potential to impact on economically important wild stocks, environmental integrity and human health.

Bacterial and Viral Diseases	Notes:	Occurrence risk	Economic risk	Environmental risk	Human Health risk
Bacterial enteritis	Observed in lobster throughout NZ, probably caused by numerous opportunistic bacteria. Occurs in lobster held intensively in sub-optimal conditions	Low	Low - only occurs in injured animals	Low	Low
Black hepatopancreas disease	Only known from one batch of experimental lobsters. Probably related to diet	Low	Low – dietary	Low	Low
Digestive epithelial virosis	RNA virus infection ubiquitous in shellfish around NZ. Probably only cause disease in stressed animals.	Low	Low - stress related	Low	Low
Epithelial erosion	Opportunistic bacterial infection associated with poor water quality. Occurs throughout NZ.	Low	Low - injured animal	Low	Low
Flavobacterial disease	These bacteria are ubiquitous in the marine environment and cause disease in stressed or damaged fish.	Medium / Low	Low - injured animal	Low	Low
Gill mycosis	Observed in holding facilities, southeast of North Island. Caused by a fungal infection that can be treated or prevented with good husbandry.	Low	Low – water quality related	Low	Low
Haemorrhagic septicaemia	Caused by Aeromonas bacteria, common in freshwater environments around NZ. May become problematic if trout culture established.	Low	Low	Low	Low
Herpes virus	The Ostreid herpes virus has been recorded within the Bay of Plenty region, causing mortalities in Pacific oysters. Also Recorded in oysters around the upper North Island. Can cause significant mortalities in cultured stock. Mainly a problem during hot summers.	High	High	Low	Low
Kidney cysts	Recorded in wild snapper from the Northeast coast of North Island. Cause unknown.	Medium	Low – in wild stock	Low	Low
Luminous vibriosis	Only occurs in cultured lobster phyllosoma	Very low	Very Low – hatchery only	Low	Low

Pustule disease	Wound invasion by opportunistic bacteria. Can occur NZ wide.	Medium	Low – injured animals	Low	Low
Rickettsiosis	Ubiquitous in many bivalves around NZ. Associated with mass mortality in scallops. No known treatment. Probably related to environmental stress. One species associated with withering foot syndrome in abalone (notifiable disease), but not recorded in paua.	Medium	Low – environmental stress	Low	Low
Shell disease	Observed throughout NZ and in wild lobsters. Usually where shell damage has occurred. Caused by bacterial or fungal infection.	Medium	Low-	Low	Low
TLS	Found in lobster holding facilities throughout NZ. Turgid Lobster syndrome is probably a response to a range of stresses such as starvation or salinity changes.	Low	Low	Low	Low
Vibriosis	NZ wide. Infection by opportunistic Vibrio bacteria that are common in the marine environment. Usually in stressed or injured stock.	Medium	Low	Low	Low
Whirling disease *Myxobolus cerebralis*	Only known in freshwater trout and salmon on the east coast of the South Island. No outbreaks recorded in salmon.	Low	High	Low	Low

Parasitic Diseases	Notes:	Occurrence risk	Economic risk	Environmental risk	Human Health risk
APX	Undescribed Apicomplexan parasite. Found in mussels and oysters around NZ. No known treatment. No disease at low infection rates.	Medium	Low	Low	Low
Bonamiosis,	Notifiable disease. Known all around the South Island in dredge oysters, also recorded Wellington Harbour. No known treatment. Infected stock should be culled. Dredge oysters are present in Tauranga Harbour and may potentially be cultured on long line systems.	Medium	High	Low – already present	Low
Flatworm,	Found in mussels and oysters all around the North Island. Sedimentation and overcrowding of the stock appears to increase incidence of worms.	Low	Low	Low – already present	Low
Haplosporidosis	Notifiable disease in oysters. One record of a haplosporidean outbreak in paua on East coast. No other infections recorded despite regular testing. Not recorded in wild oyster stocks. Treat by slaughter of stock and disinfection of site.	Medium	Medium/high	Low	Low
Mudworm	Boccardia sp. Bores hole in shell of most species. Occurs throughout NZ Sedimentation, poor husbandry and overcrowding increase occurrence.	Medium	Low	Low – already present	Low
Monogeneans	Common in wild kingfish, Benedenia seriolae and Zeuxapta seriolae have been recorded in farmed kingfish in New Zealand. Treat with Praziquantel.	High	Medium	Low – already present	Low
Fresh water Myxozoan	Myxidium parasites, common in freshwater eels, not known in seawater	Very Low	Very Low	Low	Low
Marine Myxidium disease	Recorded in snapper from Northeast coast of North Island no known disease outbreaks.	Low	Low	Low – already present in NZ	Low
Thelohania contejeani	Micropsoridean parasite recorded in Dunedin effecting freshwater crayfish (Koura)	Low	Medium	Low - already present in NZ	Low
Trichodiniasis	Protozoan ciliate infection of the gills. Seen in wild and cultured fish around NZ. Ill fish are more prone to infection. Treat with formalin bath.	Medium	Low	Low – already present	Low

Uronema	Uronema marinum is a protozoan ciliate infection found in cultured Hapuka in New Zealand. Can lead to significant mortalities in juvenile fish. Can be treated with freshwater baths, and copper sulphate.	High	Medium	Low – already present	Low
White spot disease	Protozoan (Cryptocaryon irritans). Only recorded from captive snapper in Auckland. Cage culture may increase infestation due to close proximity of hosts. Wild fish can be infected at low density without showing disease. Treatment must consider all life stages.	Low	Low	Low - probably in wild fish at low levels	Low

Marine Pests	Notes:	Occurrence risk	Economic risk	Environmental risk	Human Health risk
Asterias amurensis	North pacific sea star. Not currently in NZ. Feeds on wild and farmed shellfish and a wide variety of other marine animals	Low	Medium	High	Low
Carcinus maenas	European shore crab. Not currently known in NZ. Voracious predator. The crab is able to crush mussels and shows a clear potential to negatively threaten mussel farms.	Low	Medium	High	Low
Caulerpa taxifolia	Caulerpa is not thought to be present in the marine environment, but has been found in aquaria. Poses an environmental risk, but may only have indirect impacts on aquaculture.	Medium	Low	High	Low
Didemnum vexillum	Didemnum poses a threat to the marine farming industry because of its ability to smother man-made structures including mussel lines. It is currently known in Whangamata, Tauranga and the Marlborough Sounds, where considerable efforts are being made to control its spread.	High	Low (May be high for Aquaculture)	Medium - unknown for Wellington	Low
Eriochier sinensis	Chinese mitten crab. Not currently known in NZ, but could pose a risk to fisheries if introduced. It contributes to the local extinction of native invertebrates and modifies habitats. As well as causing erosion by its intensive burrowing activity, the crab may impact on fisheries and aquaculture industries by stealing bait and feeding on trapped fish	Low	Medium / High	Medium / High	Medium / High

Eudistoma elongatum	Australian sea squirt. First reported in New Zealand in early 2005, but was not regarded as an issue at that time given its low density and the fact that it appeared to die off over winter. It is not regarded as a serious nuisance to the aquaculture industry or the environment in its native Australia. Reported on several marine farms on Northland's east coast	Medium/high	Low	Low –lower end of thermal tolerance for colonisation	Low
Grateloupia turuturu	Invasive red alga, identified in Wellington harbour. May displace other red seaweeds. Not recorded on moorings (Neill *pers com*.).	Medium / low	Low	Low	Low
Potamocorbula amurensis	Asian Clam. Not currently known in NZ, but could pose a risk to fisheries and aquaculture if introduced.	Low	Medium / High	Medium / High	Low
Sabella spallanzanii	Mediterranean fanworm. Forms dense groups that affect aquaculture by competing for food and space. Have been found in Whangarei, Auckland, Lyttleton, Tauranga and Picton.	High	Low	Medium	Low
Styela clava	Clubbed Tunicate. Established in NZ. High-density fouling of aquaculture equipment, competition with farmed species for resources and overgrowth of shellfish. Present in Hauraki Gulf.	High	High	Medium	Low
Undaria pinnatifida	Undaria is widespread throughout NZ, The impacts of *Undaria pinnatifida* are not well understood and are likely to vary considerably depending on the location. Undaria can change the structure of ecosystems, especially in areas where native seaweeds are absent. Undaria has the potential to become a problem for marine farms by increasing labour and harvesting costs due to fouling problems on fin fish cages, oyster racks, scallop bags and mussel ropes. Heavy fouling may also restrict water flow through cages. Present in Tauranga harbour.	High	Medium / low	Medium / High Already significant populations in Bay of Plenty	Low

11. Appendix 2 Diseases Known to Occur in New Zealand Cultured Species

A summary of aquaculture experience and likely source of stock for species proposed to be farmed in the Bay of Plenty (Disease information from Diggles et al 2002)

Common name	Species	NZ Recorded Diseases	NZ Sea Aquaculture Experience	Seed supply	Occurrence
Abalone	*Haliotis iris* and *H australis*	Epithelial erosion, haplosporidosis, pustule disease, vibriosis, shell mycosis	Mortalities in sea based farmed paua have largely been attributed to opportunistic bacterial diseases occurring when paua have been damaged during transport or grading or are under environmental stress.	Hatchery	Haplosporidians outbreak recorded in the Coromandel.
Eels	*Anguilla dieffenbachii and A australis*	Flavobacterium, haemorrhagic septicaemia, myxozoan infections, neoplasm, vibriosis, white spot disease.	No significant culture of eels in NZ to date.	Wild	
Hapuka	*Polyprion oxygeneios*	Ciliates	Not currently cultured. Ciliate infections found to cause mortality in tank based juvenile cultures	Hatchery	Bream Bay, Wellington
Salmon	*Oncorhynchus tshawytscha*	flavobacterial disease, nephrocalinosis, vibriosis, whirling disease, pinhead syndrome, vibriosis, Styela clava, Didemnum vexillum	Marine farming of salmon occurs in the Marlborough sounds. Thermal tolerance of this species precludes culture in the Bay of Plenty	Hatchery	Marlborough sounds
Seahorse	*Hippocampus abdominalis*	Vibriosis, Gas bubble disease	A number of sea cage trials with seahorses have occurred. No disease outbreaks have been recorded.	Hatchery	
Yellowtail Kingfish	*Seriola lalandi*	Copepod infestation, metazoan parasites (gill flukes and skin flukes), pinhead syndrome, vibriosis	Sea cage trials in the Marlborough sounds have identified that the most commonly occurring issue in farmed kingfish is the presence of ectoparsites.	Hatchery	Parasite infections present in wild stocks and have been found in farm trials throughout N Island.
Greenlip mussels	*Perna canaliculus*	APX, digestive epithelial virosis, flatworm, mudworm, Undaria pinnatifida, Styela clava, Didemnum vexillum	Numerous cultivation trials have not recorded any significant disease related mortality.	Wild	
Dredge oysters	*Tiostrea chilensis,*	APX, bonamiosis, herpes virus, mud worm, rickettsiosis	Disease events recorded in wild populations, the main risk through culture is spread of Bonamia.	Hatchery	Bonamia in South Island and Wellington
Pacific	*Crassostrea gigas*	Flatworm, mudworm, herpes virus,	Little work on suspended culture of Pacific oysters in	Hatchery	Herpes virus recorded in the

oyster		rickettsiosis, vibriosis	Wellington region. No recorded disease outbreaks using this culture method. Records of herpes virus related mortalities within oyster hatchery in NZ.		upper North Island, including the Bay of Plenty
Sea Cucumber	*Stichopus mollis*	None recorded	Some culture work in tanks has been undertaken, and seabed culture trials associated with mussel farms. No disease reported.	Hatchery / Wild	
Seaweeds	*Pterocladia lucida, Gigartina atropurpurea, G. circumcincta, G. chilensis, Pterocladia capillacea*	None recorded.	No commercial culture of these species.	Hatchery / wild	