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Marine biosecurity risks arising from activities/stressors within the Waikato coastal marine area

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Prepared by:
Lauren Fletcher and Oliva Johnston (Cawthron Institute)

For:
Waikato Regional Council
Private Bag 3038
Waikato Mail Centre
HAMILTON 3240

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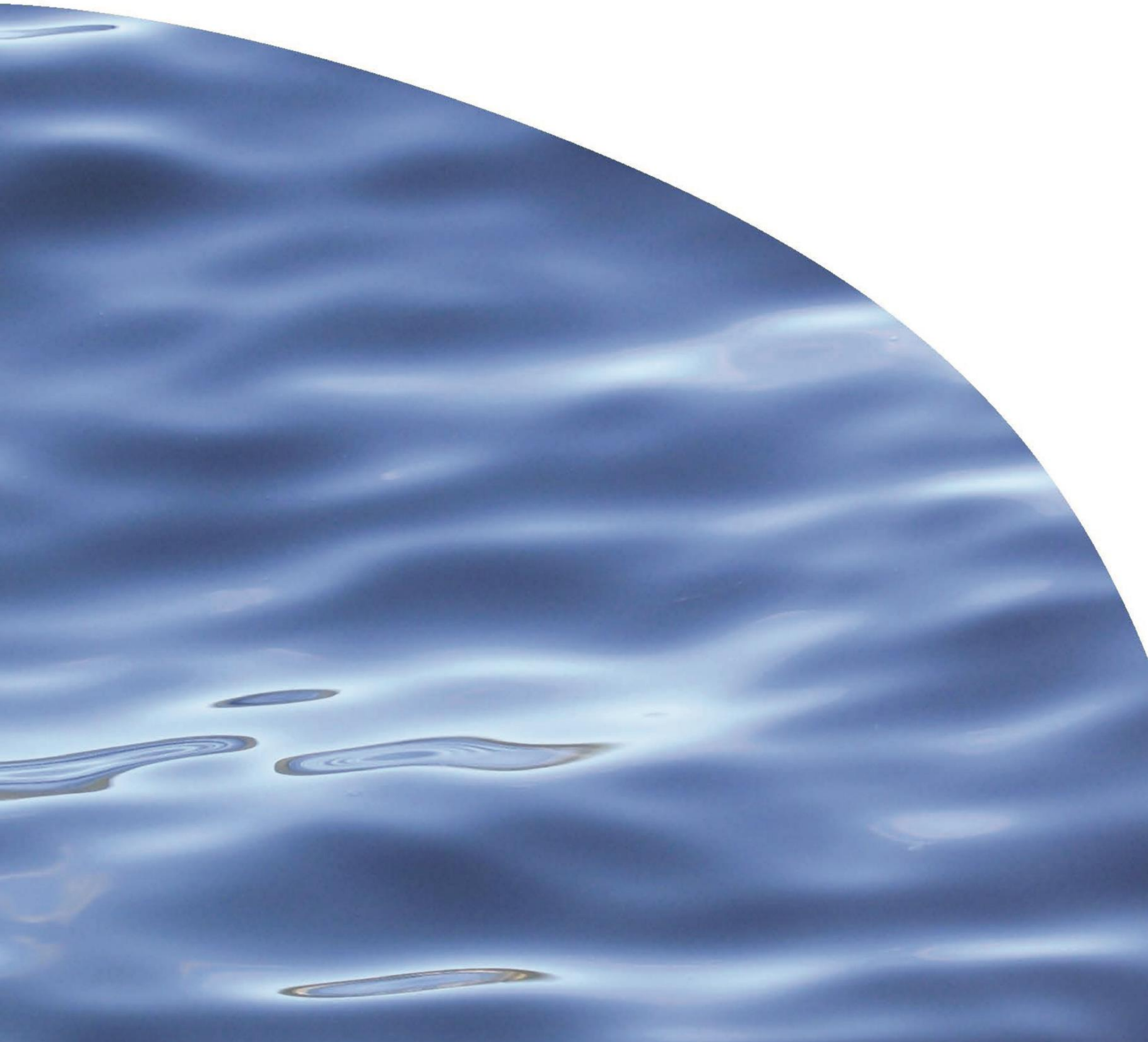

MARINE BIOSECURITY RISKS ARISING FROM ACTIVITIES/STRESSORS WITHIN THE WAIKATO COASTAL MARINE AREA

LAUREN FLETCHER, OLIVIA JOHNSTON

Prepared for Waikato Regional Council

CAWTHRON INSTITUTE
98 Halifax Street East, Nelson 7010 | Private Bag 2, Nelson 7042 | New Zealand
Ph. +64 3 548 2319 | Fax. +64 3 546 9464
www.cawthron.org.nz

REVIEWED BY:
Don Morrisey

APPROVED FOR RELEASE BY:
Grant Hopkins

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EXECUTIVE SUMMARY

Introductions of harmful marine organisms (HMOs) may have irreversible effects, including biodiversity loss and the alteration of ecosystem function. In addition, introductions may result in considerable direct economic costs, particularly with reference to high-value industries such as aquaculture and fisheries. Negative impacts to key social/cultural, amenity and public health values are also possible (i.e. impacts on food harvesting, tourism, etc.). While most risk organisms can spread through natural dispersal mechanisms, human activities in the marine environment (e.g. vessel and equipment movements, marine farm stock transfers) can increase invasive species' ranges by transporting them across barriers to their natural dispersal and may greatly accelerate rates of spread. A thorough understanding of all transport pathways and mechanisms of spread is critical, as unmanaged vectors have the potential to compromise the overall effectiveness of other biosecurity initiatives.

Regional councils are required to manage risks from harmful aquatic organisms through their responsibilities under the Biosecurity Act 1993, the Resource Management Act 1991 and the New Zealand Coastal Policy Statement 2010. A wide range of activities within the Waikato Coastal Marine Area (CMA) have implications for marine biosecurity. In managing these activities, it is important that biosecurity risks are recognised and mitigated at the earliest stage possible. In order to implement appropriate management responses, the context and magnitude of biosecurity risk associated with human activities need to be understood. This includes whether the activity introduces biosecurity risks that arise from outside the region, is likely to lead to novel biosecurity risks to the region, and the likely importance of the activity in the context of other controlled and uncontrolled activities. This report provides an overview of marine biosecurity issues relevant to a range of coastal activities, with specific appraisal of risks to the Waikato CMA. This report is intended as a resource that WRC staff can utilise for assessing marine biosecurity risks by linking certain activities with potential impacts and mitigation options.

Boating activities

The movement of vessels (both recreational and commercial) and transportable structures (e.g. oil platforms, finfish farming sea-cages) is recognised as one of the most significant vectors for the translocation of HMOs to and within New Zealand coastal waters. Key risk mechanisms include hull biofouling, the discharge of ballast and bilge water, as well as sediments or fouling associated with equipment (e.g. fishing nets, pots, anchors). Boating activities have the potential to introduce biosecurity risk through movements of the vessel and associated equipment, as well as through discharge of material through maintenance and cleaning of the vessel.

Aquaculture activities

Aquaculture operations present several vector risks that can lead to HMOs being translocated between growing areas or regions. Farm-related vessels, equipment/gear, and stock can all harbour HMOs that 'hitch-hike' during movements among farms, or between

farms and other areas (e.g. ports and marinas). Farm infrastructure can also provide a reservoir for pests and diseases to proliferate and subsequently transfer to the wider environment. Biosecurity risks associated with individual aquaculture activities are situation-specific and may differ between activities depending on the specific farm location and associated biosecurity risk profile for that area (i.e. the type and abundance of HMOs already present), farm attributes (e.g. spatial extent, stocking density/intensity) and biophysical factors (e.g. water depth, flushing characteristics).

Engineering/modification activities

Development of coastal areas can include the construction of various structures linked to land (e.g. marinas, boat ramps, jetties, seawalls) as well as those exclusively within coastal zones (e.g. navigational aids, moorings). Often these activities will require modification of the area through activities such as dredging with associated disposal of material removed. The replacement of natural, often sedimentary, substrata with hard substrata can alter the distribution of species, particularly non-indigenous species. Coastal structures can act as a 'stepping stones' for spread of HMOs, enabling species with poor dispersal mechanisms to cover greater distances over potentially unsuitable areas of habitat. Dredging or marine mining activities can also introduce biosecurity risks to a region through associated vessel movements, transfer of HMOs through spoil disposal, and in the case of some capital dredging projects, increased shipping activities.

Pest plant disturbance

The disturbance of pest plants, whether intentional or incidental, can have several biosecurity implications, particularly if the species can be spread by fragmentation. Disturbance can occur through a range of mechanisms including human-mediated activities and natural processes. Fragmentation of plant material can be facilitated by excavation work associated with the development of coastal structures (e.g. marinas, pipelines, seawalls). Similarly, the use of boat propellers, nets and similar can also dislodge plant material which are then spread through water currents or by transport vectors such as boat trailers.

Marine litter and debris

The release of marine litter into the coastal environment can provide a vector for the spread of HMOs. A range of biofouling taxa have been documented on marine litter collected from within the Waikato CMA, including hydroids, bryozoans, algae and polychaetes (including the invasive fanworm *Sabella spallanzanii*). Marine litter should be recognised as a potential vector for regional dispersal of invasive species arriving to transport hubs or areas of high urban intensification (e.g. shipping ports or marinas) and managed where possible.

Risk mitigation options

Several of the activities occurring within the CMA are under the control of WRC (i.e. require authorisation through a resource consent). The risk from HMOs should be considered and addressed when assessing consent applications. This should include the biosecurity risks associated with both the construction and operational phases of the activity, as well as the ability of new structures in the CMA to facilitate the spread of HMOs. Mitigation options will need to be assessed on a case-by-case basis, as they will depend on the nature of transfer pathways associated with existing and new types of activities, the pre-existing level of risk in the Waikato region, and the region's dynamic profile in terms of existing high-risk species.

Vessel arrivals from outside the Waikato CMA, and in some instances intra-regional movements (e.g. between the west and east coasts of the Coromandel Peninsula), likely represent the greatest biosecurity risk to the region. The most effective means of prevention is to restrict the movement of, and discharge of biofouling material from, high-risk vessels and moveable structures within the CMA. The most practical means of achieving this is through development of a marine regional pathway management plan. All risk mechanisms could be addressed as part of the plan, including hull biofouling, ballast water, bilge water and entrained water and sediments associated with gear and equipment. In addition, the movement of juvenile shellfish stock, and to a lesser extent culture-related equipment (e.g. pre-used ropes and floats), presents an on-going biosecurity risk to the region when not managed appropriately. Adherence to industry guidelines regarding stock and equipment movements should be promoted or where possible regulated (i.e. through a requirement for farm-specific Biosecurity Management Plans for new developments).

Voluntary measures, such as a code of practice with the shipping industry to limit ballast water discharges within specific areas of high-value, could also be considered. Similarly, raising awareness among the recreational boating community of the risk of spreading HMOs via mechanisms such as bilge water, trailered watercraft, and fouled equipment and gear (e.g. by erecting signs at marinas and boat ramps) may be useful. This could include further education/awareness campaigns (e.g. promotion of the 'Clean Below? Good to Go' campaign for hull biofouling) targeting vessel operators regarding best practice options for reducing biosecurity risks associated with these mechanisms.

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1. INTRODUCTION

1.1. Background

The introduction and establishment of non-indigenous species in the marine environment can have widespread economic and ecological impacts. Waikato Regional Council (WRC) is responsible for managing a range of activities and developments in the coastal zone that have implications for marine biosecurity. In managing these activities, it is important that biosecurity risks are recognised and mitigated at the earliest stage possible, as preventative measures are generally more achievable and cost-effective than reactive measures once potential harmful marine organisms have become established or spread. WRC have engaged the Cawthron Institute (Cawthron) to provide a technical report that aids in identifying marine biosecurity threats and informing associated management of these risks.

1.2. Report scope and structure

This report provides an overview of marine biosecurity issues relevant to a range of coastal activities and stressors in New Zealand at the time of writing, with specific appraisal of risks to WRC's Coastal Marine Area (CMA; Figure 1).

The report is structured into five main sections:

- overview of harmful marine organisms and context for understanding regional biosecurity risk
- framework for risk identification, including guidance on the context and magnitude of risks with reference to the Waikato region
- identification of biosecurity implications associated with a range of activities or stressors that WRC has responsibility for under the Resource Management Act 1991 and Biosecurity Act 1993. This includes an explanation of the processes involved, the potential impacts that may arise and the degree of risk involved for each activity/stressor
- guidance on how biosecurity risks associated with the specific activities or stressors could be mitigated, including an assessment of the feasibility and limitations of any potential mitigation measures
- identification of critical knowledge gaps and research priorities pertaining to biosecurity risk assessment and mitigation, with a description of opportunities for WRC (or other entities) to address these gaps.

The activities/stressors addressed in this report were agreed on with WRC as part of an earlier scoping exercise and are priorities in terms of marine biosecurity risk to the region. This report is intended as a resource that WRC staff can utilise for assessing marine biosecurity risks by linking certain activities/stressors with potential impacts and mitigation options. The report should not be regarded as a systematic risk assessment for each activity, but rather a resource to identify the main issues, as well as identify key knowledge gaps or areas of uncertainty.

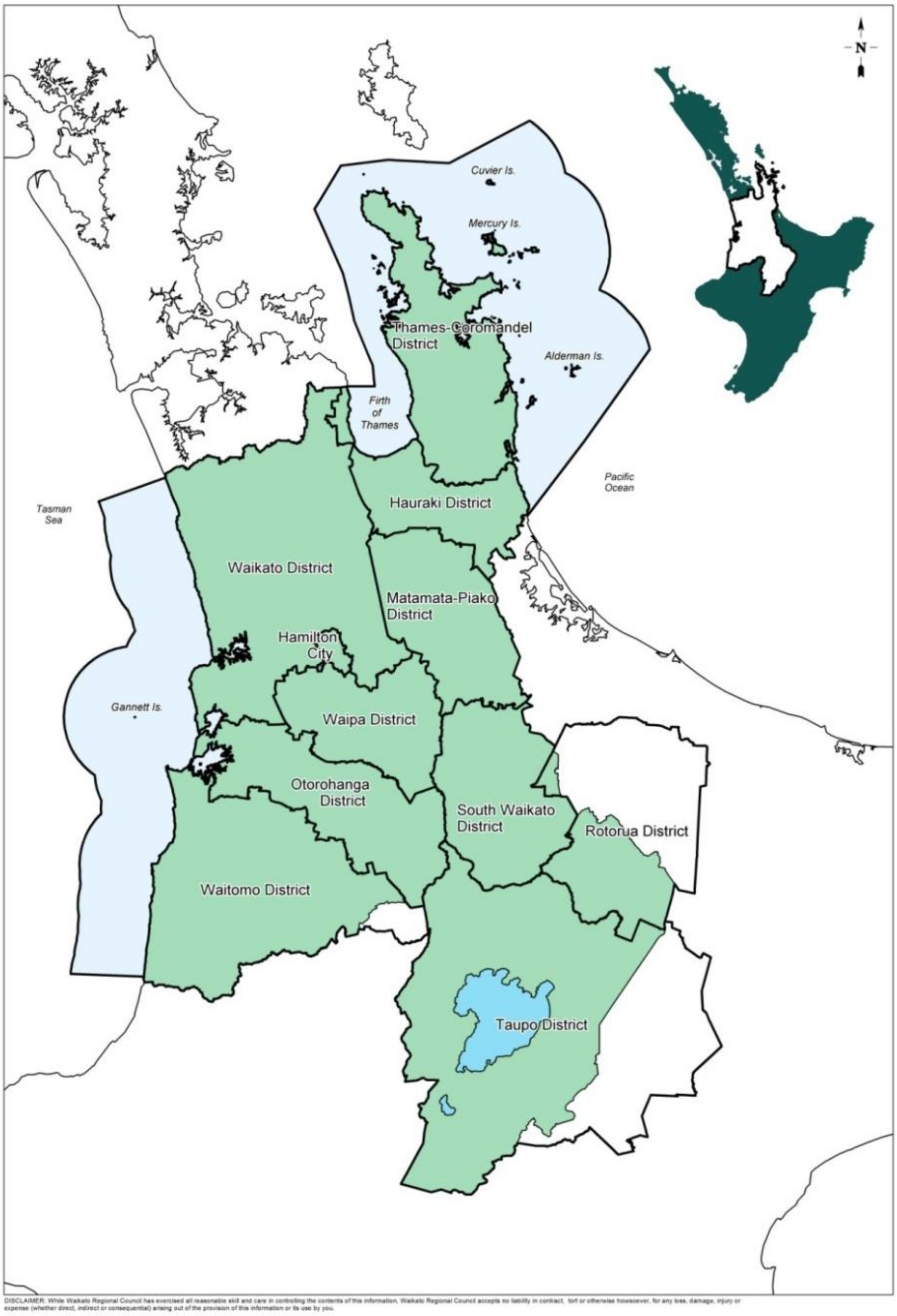


Figure 1. The Waikato Coastal Marine Area (CMA; light blue shading) includes west coast harbours (e.g. Aotea, Kawhia, Raglan), the Firth of Thames and south-eastern Hauraki Gulf, as well as the coastline and many estuaries along the eastern side of the Coromandel Peninsula. Source: Waikato Regional Council.

2. HARMFUL MARINE ORGANISMS AND THEIR SPREAD

2.1. Background

Biological invasions are one of the major human-associated threats to ecosystems and biodiversity, with non-indigenous species (NIS) shown to have considerable ecological and economic impacts on a global scale (Simberloff *et al.* 2013). At present, New Zealand remains free of some of the world's most notorious invasive marine species, no doubt aided by geographical isolation and comparatively strict border controls. However, the last 15–20 years has seen an increased prevalence of invasions and associated adverse effects within our marine environment (Goldson *et al.* 2015). The vast increase and changing patterns of vessel movements, along with changing environmental conditions in marine environments, mean emerging and introduced pests and diseases remain a considerable threat to a range of values.

At least 330 NIS have been introduced to New Zealand's marine environment (MPI 2015), most into areas of high vector activity such as commercial shipping ports and marinas. Approximately half of these species are now recognised as *established* in New Zealand, meaning they have developed a viable self-sustaining population or populations. Following establishment, some NIS can proliferate in their new environments and may cause, or be inferred to cause, adverse effects. Although recorded marine NIS in New Zealand are numerous, only a few are demonstrated to cause economic or ecological harm and are thus recognised as marine 'pest' species (Falk-Petersen *et al.* 2006), and it is these which typically receive public attention. It should also be noted that organisms that are native to New Zealand, or those deemed cryptogenic[1], can also cause adverse effects to key values in certain circumstances. For example, aquaculture can be adversely affected by the proliferation of biofouling species, many of which are native to New Zealand (Forrest *et al.* 2014).

In this report, we take the broadest view and consider biosecurity risks posed by *any* species with the potential to cause adverse effects. We use the term 'harmful marine organism' (HMO), which has previously been defined as any marine organism, indigenous or non-indigenous, and including any pathogen or disease, that has the potential to cause harm to valued marine species, ecosystems or environments (see Inglis *et al.* 2013; Sinner *et al.* 2013). As such, this term encompasses macroscopic species (i.e. marine animals and plants usually visible to the eye) as well as microscopic species such as pathogens, parasites, and algae associated with biotoxin production and harmful algal blooms (HABs).

In this section we provide a high-level overview of HMOs that pose biosecurity risks in New Zealand and their potential impacts, their modes of introduction and spread in the context of the 'chain of events' that may lead to regional biosecurity risk, and the

[1] Organisms whose geographic origins (i.e. whether they are native or non-indigenous) are uncertain.

general approaches available for mitigation. The reason for including this generalised section is to avoid unnecessary repetition of processes, risks and impacts associated with the various activities covered in the report that are likely to display commonalities. The reader is directed to additional relevant literature where it exists.

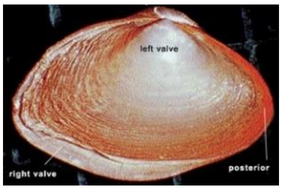
2.2. Types of harmful marine organisms and their associated impacts

Numerous studies across a wide range of taxonomic groups have attempted to define what characteristics determine whether a species is likely to be invasive, as well as whether a community is vulnerable or resistant to invasion (Stachowicz *et al.* 2002 and references therein). The underlying traits believed to contribute to successful establishment include a lack of natural enemies, ability for habitat modification, association with human activities, genetic variability and phenotypic plasticity, and a high degree of competitiveness. More generally, successful colonists are often species with high reproduction rates, a broad tolerance to a wide range of environmental conditions, as well as an ability to colonise a variety of habitat types (Troost 2010).

The present focus for central and local government in New Zealand is on marine NIS that have been identified as high-risk, and subsequently classified as 'unwanted organisms' under the Biosecurity Act 1993 and other legislation. At the time of writing, eight marine pest species are specified (Table 1). Each species has a prior history of invasion outside New Zealand, is known to have significant impacts on native ecosystems or economic values in the regions it has invaded, and is capable of surviving in New Zealand coastal waters (Wotton & Hewitt 2004). Three species have since become established in New Zealand (the Asian kelp *Undaria pinnatifida*, the clubbed tunicate *Styela clava* and the Mediterranean fanworm *Sabella spallanzanii*), including at locations within the Waikato CMA. Early detection of incursions of the remaining five species (the green alga *Caulerpa taxifolia*, the Asian clam *Potamocorbula amurensis*, the Chinese mitten crab *Eriocheir sinensis*, the European shore crab *Carcinus maenas*, and the Northern Pacific sea star *Asterias amurensis*) is the focus of the Ministry of Primary Industries (MPI) funded national Marine High Risk Site Surveillance (MHRSS) programme.

Several other high-profile pest species are currently present in New Zealand that have, for various reasons, not been formally designated unwanted organisms (see Table 1). Species of note include the Asian paddle crab (*Charybdis japonica*), the droplet tunicate (*Eudistoma elongatum*), the Asian date mussel (*Arcuatula senhousia*), the Australian 'cunjevoi' tunicate (*Pyura doppelgangera*), the vase tunicate (*Ciona intestinalis*), and the carpet tunicate (*Didemnum vexillum*). Of these species, only *D. vexillum* and *C. intestinalis* are known to be established within the Waikato CMA, although *C. japonica* is also suspected based on several recent detections of individuals of this species.

Table 1. Non-indigenous species designated unwanted organisms under the Biosecurity Act 1993. Their recorded distribution in New Zealand is indicated, including reference to the Waikato Coastal Marine Area (bolded). Modified from Piola and Forrest (2009).

Scientific and common name	New Zealand distribution	Example
Asterias amurensis Northern Pacific sea star	Not recorded	
Carcinus maenas European shore crab	Not recorded	
Caulerpa taxifolia Green aquarium weed	Not recorded	
Eriocheir sinensis Chinese mitten crab	Not recorded	
Potamocorbula amurensis Asian clam	Not recorded	
Sabella spallanzanii Mediterranean fanworm	Northland, **Hauraki Gulf** and **Firth of Thames**, Tauranga, Wellington, Picton, Nelson, Golden Bay, Lyttelton	
Styela clava Clubbed tunicate	Northland, **Hauraki Gulf** and **Firth of Thames**, Tauranga, Wellington, Picton, Nelson, Golden Bay, Lyttelton, Dunedin	
Undaria pinnatifida Asian kelp	Widespread in harbours between Stewart Island and Auckland, including in the **Hauraki Gulf** and **Firth of Thames**	

2.2.1. Potential impacts to core values

The introduction or spread of an HMO can lead to impacts across a range of values. With reference to the marine environment, values are qualities, uses or potential uses that people and communities appreciate about these spaces and wish to see recognised in their ongoing management. Impacts to ecological, economic, public health, amenity and social/cultural values are most commonly discussed with regards to the introduction of HMOs, however, the specific level of impact is often challenging to quantify. Potential effects are often inferred from experience elsewhere, but invasiveness of a species may vary between locations, within geographical regions, as well as across years. Populations of some HMOs proliferate rapidly only to taper off a few years later, possibly due to overexploitation of resources, native systems adapting, or other mechanisms still not fully understood. Other well-established species can appear harmless for decades before their populations suddenly 'explode' (e.g. the barnacle *Balanus trigonus* with reference to the Coromandel mussel industry). Recent analyses suggest that economic costs to the country from specific pest species could be substantial (Nimmo-Bell 2009; Soliman & Inglis 2018) and a range of other values (e.g. ecological, natural character, public health) can be adversely affected.

Depending on the type of organism, HMOs can have very different types of impacts within coastal environments. Impacts are very much context dependent, and can vary considerably based on HMO attributes, as well as resource levels, abiotic conditions, and community structure of the invaded habitats (Thomsen *et al.* 2014).The Waikato CMA encompasses areas with considerable ecological and conservation value, with physical habitats including expansive tidal flats, extensive subtidal soft sediments, and fringing rocky reef habitats (see Forrest *et al.* 2011). A number of areas of significant conservation value have been identified in the region (see Figure 2). Introductions of HMOs into these areas may have irreversible effects, including biodiversity loss and the alteration of ecosystem function. In addition, introductions affecting marine industries within the Waikato CMA may result in considerable direct economic costs, particularly with reference to high-value industries such as shellfish aquaculture and fisheries (see Soliman & Inglis 2018). Negative impacts to key social/cultural, amenity and public health values are also possible (i.e. impacts on food harvesting, tourism, recreational fishing).

Below we provide generalised information on the key types of HMOs, including a description of susceptible habitats and potential impacts to core values (Table 2).

Figure 2. Areas of Significant Conservation Value (ASCV) within the Waikato Coastal Marine Area (CMA). Careful consideration to the significant conservation values present is required when making applications to use or develop resources in an ASCV. Source: Waikato Regional Council.

Table 2. Generalised information on the key types of harmful marine organisms (HMOs), including examples of high-profile species, a description of susceptible habitats and potential impacts to core values. * indicates species not currently present in New Zealand.

Type of HMO	Description	Example species	Susceptible habitats	Potential impacts
Filter-feeding invertebrates	Often occur in very high densities and can modify natural ecosystems through the possible exclusion of native species. High biomass of problematic fouling organisms increases the time and costs of harvesting and factory processing of cultured shellfish species. Can remove potential food sources from the water column so impacts to nutrient availability are possible. May compete for food and space with cultured species such as oysters and mussels.	*Sabella spallanzanii* *Styela clava* *Didemnum vexillum*	Submerged artificial structures Cultured shellfish stock Soft-sediment	Ecological Economic Social/cultural Amenity
Mobile predators	Directly prey upon and compete with indigenous species. They feed on a wide variety of prey including those of commercial importance. Invasive mobile predators such as sea stars and crabs can establish large populations and are known to be voracious feeders of shellfish species including mussels, scallops, oysters and clams, directly impacting on social/cultural and commercial values.	*Charybdis japonica* *Eriocheir sinensis** *Carcinus maenas** *Asterias amurensis**	Rocky reef Soft-sediment Submerged artificial structures Cultured shellfish stock	Ecological Economic Social/cultural Amenity
Infauna species	Infauna species live in the sediments of the seafloor and include crabs, tubeworms and shellfish. They often reach very high densities and can cause dramatic changes to soft-sediment communities. They are very successful outcompeting native species for available food and space. Burrowing infauna have been documented to cause weakening and collapse of river and estuary banks.	*Eriocheir sinensis** *Potamocorbula amurensis**	Soft-sediment	Ecological Economic Social/cultural Amenity
Macroalgae species	They form dense populations, have rapid growth rates and high reproductive output, can colonise a variety of substrata and tolerate wide-ranging temperatures and depths. Establishment can alter light availability and flow regime, compete with native canopy forming species, can change the presence of understory and epibiotic assemblages, and can alter macrofauna abundance and diversity.	*Undaria pinnatifida* *Sargassum horneri** *Caulerpa taxifolia**	Rocky reef Submerged artificial structures Cultured shellfish stock	Ecological Economic Social/cultural Amenity

Type of HMO	Description	Example species	Susceptible habitats	Potential impacts
Harmful algal blooms (HABs)	Various species of microscopic phytoplankton that produce biotoxins. These compounds can accumulate in shellfish and affect the health of human consumers or the wider ecosystem. Can lead to the closure of harvest in shellfish aquaculture areas. There is ongoing nationwide surveillance to detect target HAB species within and adjacent to areas of importance for aquaculture or recreational shellfish gathering.	*Gymnodinium* spp. *Vulcanodinium rugosum* Cyanobacteria	Surface waters	Public health Economic Social/cultural Ecological
Pathogens and parasites	Can cause collapses of fish and shellfish stocks having severe effects on aquaculture and commercial, cultural and recreational fisheries. Some pathogens and parasites may affect human health.	*Bonamia* spp. Ostreid herpes virus type 1 *Boccardia* spp. *Vibrio* spp.	Cultured shellfish stock	Public health Economic Social/cultural Ecological

2.3. Chain of events leading to biosecurity risk

For adverse effects from HMOs to occur within the Waikato CMA a chain of events must occur (see Figure 3). While most risk organisms can spread through natural dispersal mechanisms, human activities in the marine environment (e.g. vessel movements, equipment movements, marine farm stock transfers) provide an added dimension to dispersal (Dodgshun *et al.* 2007; Inglis *et al.* 2010b). Human activities can increase invasive species' ranges by transporting them across barriers to their natural dispersal and may greatly accelerate rates of spread. Management of biosecurity risk to the Waikato CMA focuses on interrupting the chain of events to prevent establishment and adverse effects.

While spread by natural dispersal is of critical importance in the establishment of self-sustaining HMO populations, anthropogenic transport mechanisms generally play a significant role in regional and national scale spread. There are a number of human activities in the marine space that may, intentionally or unintentionally, move an HMO from one place in New Zealand to another. These activities are generally called 'pathways', and include a range of industries operating within the marine environment (e.g. maritime transport, commercial fishing, aquaculture; see Inglis *et al.* 2013). Associated with pathways are the physical means by which the organism is transported, referred to as 'vectors'. Vectors include vessels and moveable structures (e.g. sea cages, oil rigs) or equipment (e.g. fishing gear) that move among different geographic locations (both within and outside a region), which could facilitate the spread of marine pests. The primary focus of effective biosecurity management is the control of vector risks (Hewitt & Campbell 2007; Campbell 2009). A thorough understanding of all transport pathways and mechanisms of spread is critical, as unmanaged vectors have the potential to compromise the overall effectiveness of other biosecurity initiatives. Below we provide an overview of the main vectors and key mechanisms of transport of HMOs by these vectors.

2.3.1. Movement of vessels or structures

Vessel or structure movements are generally considered the most important anthropogenic vector for HMO spread (Ruiz *et al.* 1997; Molnar *et al.* 2008; Seebens *et al.* 2013). Marine organisms can be transported as part of biofouling communities on submerged surfaces (including within sea chests[2]), in ballast and bilge water, or within debris or sediments associated with equipment or gear.

Hull biofouling

Biofouling refers to the gradual accumulation of organisms and biogenic structures on artificial surfaces submerged in marine or freshwater environments (Durr & Watson 2010). These assemblages can vary greatly in complexity and composition but may typically include microbial organisms, sessile (i.e. attached) algae and invertebrates

[2] Sea chests are water intake chambers that are recessed into the side of the hull of large vessels.

(e.g. mussels, bryozoans, sponges, etc.). Many of the better-known pest species are sessile biofouling organisms. Biofouling can also provide habitat for mobile pest species such as crabs (Davidson *et al.* 2008).

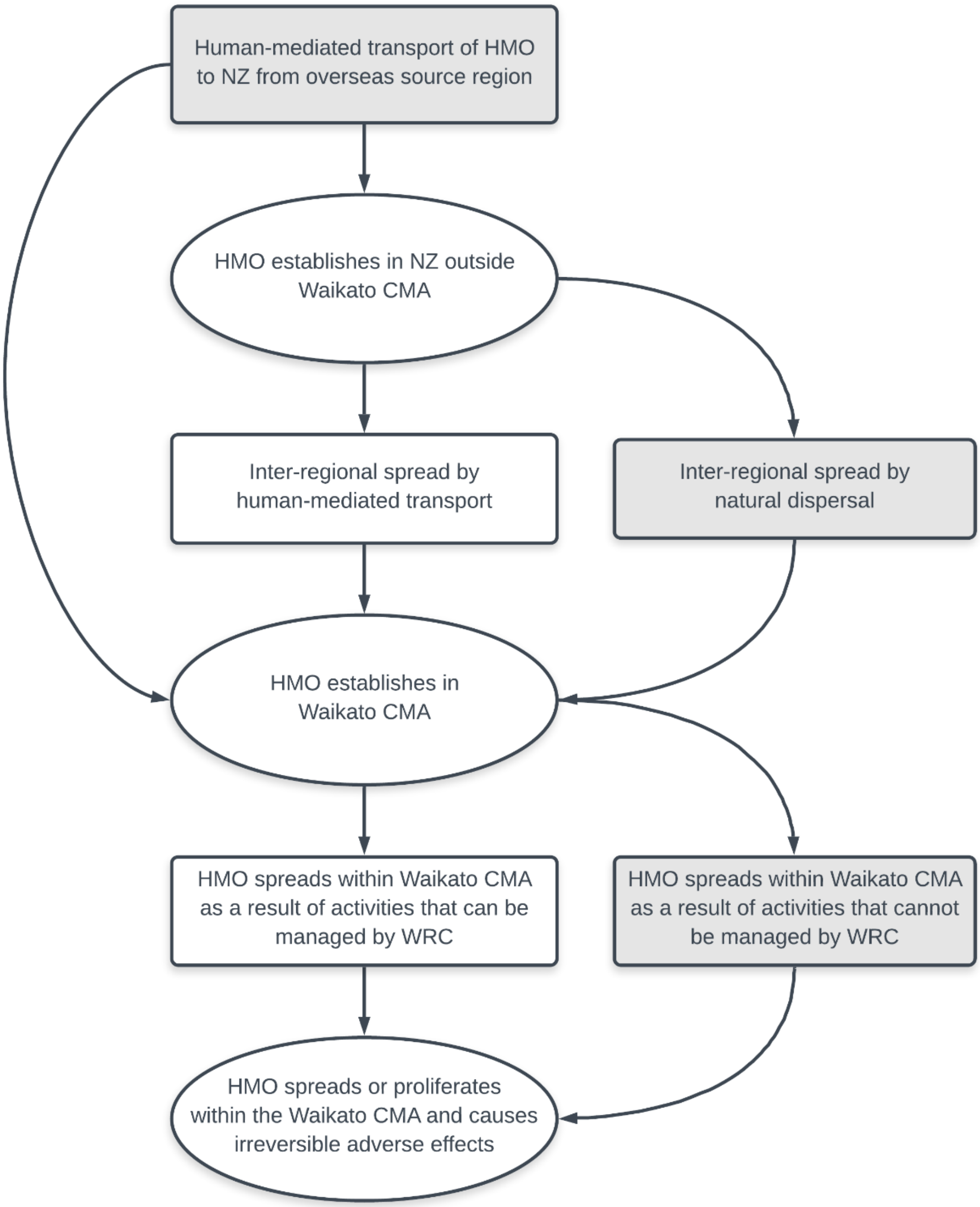


Figure 3. Conceptualisation of processes and events that could lead to the establishment or spread of Harmful Marine Organisms (HMOs) in the Waikato Coastal Marine Area (CMA). This depicts (from the top down) the processes of human-mediated or natural spread of HMOs (rectangles), with grey rectangles representing activities that are beyond the control of Waikato Regional Council (WRC) (e.g. spread through natural dispersal mechanisms). Modified from Figure 1 in Sinner *et al*. (2013).

Biofouling organisms often accumulate on vessel hulls, within internal seawater systems and within ‘niche’ areas (e.g. sea chests, bow thrusters and tunnels, rudders, anodes, bilge keels) that are recessed or protected from water drag, or which are not adequately protected by an antifouling coating (Bell *et al.* 2011). A recent study of biofouling noted that more than 80% of the total species richness on vessels sampled was recorded from niche areas (Inglis *et al.* 2010a). Whereas external hull biofouling assemblages mainly consist of sessile species, large vessels (including merchant ships, and some cruise ships and fishing vessels) have sea chests, which are niche areas that can contain the adult life stages of mobile species like crabs and sea stars (Coutts & Dodgshun 2007).

The role of hull biofouling in transferring HMOs is recognised as a particularly important biosecurity risk mechanism in New Zealand (Coutts & Taylor 2004; Hewitt *et al.* 2009b; Hopkins & Forrest 2010a; Inglis *et al.* 2010a). The study by Inglis *et al.* (2010b) described 187 different biofouling species on 508 international vessel arrivals in New Zealand. Almost 60% of the vessels had NIS on their hulls. Of the 187 species, 128 were non-indigenous, and 73% of the NIS were not known to be established in New Zealand. Pest spread by hull fouling appears to be especially important for vessels that travel at speeds slow enough (< 10 knots; e.g. barges, towed structures) to enable the survival of associated fouling organisms (Coutts *et al.* 2010; Hopkins & Forrest 2010b).

Ballast water

Ballast water is the water placed in a ship to increase the draft, change the trim or regulate stability. It includes associated sediments, whether within the water column or settled out in tanks, sea chests, anchor lockers, or internal pipework (Inglis *et al.* 2013). Ballast water is carried mainly by merchant vessels, some cruise ships and certain types of drilling rig. Depending on the source, ballast water may contain HMOs or their dispersive life stages. Examples include:

- planktonic dispersal stages of marine organisms (e.g. invertebrate larvae or seaweed spores),
- fragments of colonial organisms (e.g. fouling sea squirts),
- harmful algal bloom species and other plankton, including cyst stages.

If ballast water is subsequently discharged at another location, any associated HMOs may be transferred. Ballast water movements have been implicated in the spread of many HMOs, including pathogenic micro-organisms (Carlton 1985; Drake *et al.* 2007; Barry *et al.* 2008). In addition to international vessel arrivals directly from overseas, ballast water may be discharged by international ships on multi-port domestic routes, as well as by domestic cargo ships (Sinner *et al.* 2012). Such discharges could lead to inter-regional risk among ports or near deballasting areas *en route* to ports. The biosecurity risks associated with ballast water are influenced by the volume transported and discharged by the vessel, the number of vessels on the pathway discharging ballast, the number of potential HMOs present at the site of uptake, season, transit time, and the environmental similarity of the source and receiving environments (Inglis *et al.* 2013 and references therein).

Bilge water

Vessels will often take on seawater as part of normal operations, which then accumulates on or in the deck or bilge spaces. Bilge water is any seawater that accumulates within the hull of a vessel (including in the engine room of larger vessels) and in the bilge sumps of smaller vessels, is contained in or on the vessel (e.g. for fish or bait), or is uncontained on the deck area of a vessel including in gear storage areas (Inglis *et al.* 2013). Compared to ballast water, the volumes of bilge water on board a vessel are very small; however, this water may still contain HMOs or their dispersive life-stages. A recent survey of 30 small vessels operating within the Top of the South region identified 118 and 45 distinct taxa within the bilge water on board through molecular and morphological analyses, respectively (Fletcher *et al.* 2017). Bilge water from small vessels is not usually treated prior to discharge to sea, so it is conceivable that HMOs present may be viable at the time of discharge. Recent experimental work found that larvae and fragments of three common biofouling species were able to pass through a bilge pump system relatively unharmed (Fletcher *et al.* 2017). By contrast, larger vessels are required to separate oil and water using filtration systems, centrifugation, or carbon absorption (Inglis *et al.* 2013; Sinner *et al.* 2013), so the biosecurity risk from these discharges may be less.

2.3.2. Movement of equipment or gear

A wide variety of equipment is used in association with the marine environment, for example, dive gear, fishing gear, ropes and chains, anchors and other ground tackle and marine farming lines (Sinner *et al.* 2013). Movement of these items can transport HMOs within associated water or sediments and as fouling or entanglement. The risk of spreading HMOs due to the movement of such items exists for all pathways, but is probably greatest in the commercial fishing, aquaculture and recreational sectors due to the volume of gear movements in those sectors.

Entrained water and sediments

Water and sediments are often associated with gear or equipment, for instance with wet dive gear or amongst fishing nets or mussel lines. Sediment can contain a variety of marine organisms, which may include NIS or other potentially harmful species (Hewitt *et al.* 2009b). When compared to ballast or bilge water, the volume of water associated with movements of these items is generally low. That being so, it is still possible for the dispersive life stages of HMOs to be transported between areas or regions via this mechanism (Darbyson *et al.* 2009).

Associated fouling or entanglement

As with vessel hulls, biofouling organisms can accumulate on any gear or equipment that has spent an extended period in the water. In addition, with some types of equipment (e.g. anchors, fishing nets, scallop dredges etc.) it is common for marine organisms to become entangled during routine operations. These organisms can then be transported to new areas or regions along with the gear or equipment being moved.

2.3.3. Movement of livestock and bait

The movement of livestock (e.g. shellfish spat or seed, harvested fish or marine species that are subsequently returned to the environment) and bait between areas or regions can lead to the transfer of any associated HMOs (Sinner *et al.* 2013). The holding water in which the livestock or bait are transferred also poses a biosecurity threat. The movement of livestock or bait is primarily associated with the aquaculture and commercial fishing sectors, as well as to a lesser degree sport and recreation activities.

3. BIOSECURITY MANAGEMENT

3.1. Marine biosecurity management in New Zealand

Biosecurity has been defined as management of the risks posed by introduced (i.e. non-indigenous) species to environmental, economic, social and cultural values (Hewitt *et al.* 2004). In New Zealand, biosecurity management is administrated by MPI who implement the Biosecurity Act 1993. MPI are primarily concerned with the prevention of pest establishment in New Zealand and managing risk to any national or regional value associated with inter-regional vector movement (see MAF 2011). This includes border and pre-border management of risk vectors, surveillance at high risk points of entry (shipping ports) to facilitate early detection of high risk NIS, response to new NIS incursions, national management of domestic vectors to limit spread, control programmes for priority pests, and related communications, for example to educate and raise awareness (see Sinner *et al.* 2012). The 2010 New Zealand Coastal Policy Statement (NZCPS) also provides guidance on biological risk management. Under Policy 12 of the NZCPS, regional councils are required to manage risks to marine biosecurity from harmful aquatic organisms.

3.1.1. Existing legislation

Sinner *et al.* (2013) provided a comprehensive assessment of the statutory framework in place to manage marine pests in New Zealand, including a detailed description of the Biosecurity Act 1993, the Resource Management Act 1991 and the New Zealand Coastal Policy Statement 2010 and the roles of these documents in the management of HMOs in New Zealand. A high-level overview of key legislation relevant to managing vessel risk mechanisms is provided below, largely sourced from Floerl *et al.* (2015).

Biosecurity Act 1993

The Biosecurity Act is the key legislation for managing marine pests in New Zealand. Key provisions and regulatory mechanisms available under the Biosecurity Act to manage marine pests include:

- national policy direction
- national and regional pest management plans
- national and regional pathway management plans
- government–industry agreements
- craft risk management standards
- controlled area restrictions
- small scale management programmes
- unwanted organism declarations.

The statutory provisions enabling pathway management plans and government-industry agreements were added by amendments to the Act in late 2012. During marine response activities, the Biosecurity Act can also be used to direct vessel owners to comply with instructions from response staff (termed a Notice of Direction), such as removing the vessel to land or treating/removing biofouling present.

Resource Management Act 1991

The Resource Management Act can be used to manage vectors and pathways within a region. For example, a condition in a resource consent for drilling rigs being offloaded (from a heavy-lift vessel) in Admiralty Bay was the requirement to meet the new hull biofouling standard (CRMS, see below) before it became compulsory. This condition also applied to the heavy-lift vessel and the supply vessels used to tow the rigs up to the Taranaki Basin.

Resource consents issued for swing moorings in the Nelson City Council (NCC) jurisdiction include conditions that require that mooring fittings are inspected biennially by a suitably qualified and experienced inspector. In addition to being structurally sound, correctly positioned and labelled, and of the configuration specified, they are also required to be ‘free from invasive marine organisms in the opinion of Council’s Monitoring Officer’. Swing mooring consents issued by Tasman District Council (TDC) and Marlborough District Council (MDC) also require regular inspections, however there are presently no conditions relating to invasive species or biofouling accumulation.

Regulations for ballast water discharge

Ballast water from international vessels is managed through MPI’s Import Health Standard (IHS) of the Biosecurity Act 1993 (MPI-IHS 2016), and by Maritime New Zealand under the Maritime Transport Act 1994 and the Marine Protection Rules Part 300 (MNZ-MPR 2016), which give effect to the International Convention for the Control and Management of Ships’ Ballast Water and Sediments 2004 (BWMC). Except for emergency discharge, the regulations require that ballast water discharged to New Zealand waters has been treated or exchanged in mid-ocean *en route* to New Zealand. Vessels wanting to discharge ballast in New Zealand waters are required to submit to MPI a Vessel Ballast Water Declaration form and seek approval before arrival. The IHS also prohibits the discharge of sediment to New Zealand waters from ballast tanks, anchor lockers, sea chests or other sources. Vessels from Port Phillip Bay and Tasmania, in Australia, are specifically prohibited from discharging any ballast water, as these are considered high risk source regions for HMOs. Management approaches such as ballast water exchange are not feasible for vessels on domestic routes, as the port-to-port voyage time is too short. The only instance in New Zealand that we are aware of where ballast water is managed by a regional council occurs in Fiordland (Sinner *et al.* 2009).

Craft Risk Management Standard for hull biofouling

In 2014, the Ministry for Primary Industries introduced a Craft Risk Management Standard (CRMS) that incorporates ‘hull hygiene’ and biofouling management requirements for vessels entering New Zealand territorial waters. The CRMS officially came into force on 15 May 2018 and requires all vessels to complete a biofouling declaration prior to entering New Zealand and to arrive with a ‘clean hull’ in accordance with specified biofouling thresholds. There are separate requirements in terms of allowable amounts and types of biofouling depending on whether the vessels are classified as ‘short-stay’ or ‘long-stay’ (MPI 2014).

3.1.2. Standards, guidelines or codes of practice

In addition to the above regulations, industry-specific recommendations are often provided in the form of standards, guidelines or codes of practice.

In-water cleaning guidelines

The Anti-fouling and In-water Cleaning Guidelines[3] were released by the Commonwealth of Australia in June 2013, replacing the 1997 ANZECC Code of Practice for Anti-fouling and In-water Hull Cleaning and Maintenance. Whereas the Code of Practice in 1997 largely discouraged in-water cleaning, the 2013 guidelines support in-water cleaning under certain circumstances. The guidelines were developed through an extensive process of stakeholder consultation and are endorsed by the Australian government and MPI. The guidelines have no statutory effect in New Zealand but can be used as the basis for the development of codes of practice, Resource Management Act rules or measures under biosecurity instruments such as regional pathway management plans.

The guidelines recommend best practice approaches for the application, maintenance, removal and disposal of antifouling coatings, and the management of biofouling and invasive aquatic species on vessels and movable structures in Australia and New Zealand. The guidelines also contain a decision-support tool that uses risk factors (e.g. paint coating type, age, biofouling size and origin) to assist decision-makers about appropriate in-water cleaning practices. MPI have also produced guidelines on balancing the potential environmental costs and benefits of in-water cleaning as a biosecurity risk management tool (Morrisey *et al.* 2013). They concluded that the appropriateness of in-water cleaning is dependent on factors such as vessel type, level and type of fouling, location, and frequency. In-water cleaning was considered unacceptable, even when capture technologies are used, for all international vessel types with a level of fouling (LOF) > 3 (i.e. ≤ 15% macrofouling cover). In-water cleaning was also considered unacceptable, even when capture technologies are used, for all domestic vessel types with a LOF > 3 and carrying suspected NIS.

[3] http://www.agriculture.gov.au/biosecurity/avm/vessels/biofouling/anti-fouling-and-inwater-cleaning-guidelines

Guidance material for boaters

MPI has developed the resource 'Clean Boats-Living Seas', which encourages boaters to keep their hulls clean (to not exceed slime layer biofouling) and be on the look-out for target pests or unusual species. Another initiative is New Zealand's Clean Boating Programme (www.cleanboating.org.nz) developed by the New Zealand Marina Operators Association, part of which provides guidance on hull biofouling and cleaning. In addition, the Top of the North Marine Biosecurity Partnership (made up of Auckland Council, Bay of Plenty, Hawke's Bay, Northland and Waikato Regional Councils) actively promote their 'Clean Below? Good to Go' message to boat operators, encouraging the practice of cleaning vessels before moving to a new harbour or waterbody[4].

Industry codes of practice

While biosecurity management measures are often focused on specific one-off activities (e.g. movement of an oil rig), broader industry-specific codes of practice (COPs) for managing biosecurity risks do exist for some sectors. Examples include the Deed of Agreement between the cruise ship industry and Environment Southland with regards to ballast water discharge within the Fiordland Marine Area, as well as COPs developed by several universities and research providers to reduce biosecurity risk from their research and educational activities.

To specifically address risks to and from aquaculture, Aquaculture New Zealand (AQNZ) and MPI are developing a range of approaches to improve marine biosecurity management in the marine farming industry. There are a number of industry-specific recommendations provided in AQNZ's 'Sustainable Management Framework' (SMF) documents which have been produced for the mussel, Pacific oyster and salmon sectors. These documents outline threats common to aquaculture operations in New Zealand along with a set of voluntary guidelines to minimise biosecurity risks. In addition, AQNZ and MPI have jointly produced the 'Aquaculture Biosecurity Handbook' and associated technical document, which provides marine farmers with guidance to strengthen on-farm biosecurity management. The SMF documents and Biosecurity Handbook are both available online[5].

Central government have developed the Government Industry Agreement for Biosecurity Readiness and Response (GIA), which is a partnership between government and industry for improving New Zealand's biosecurity. Participants agree the priority pests and diseases of most concern to them as a sector and on actions to minimise the risk and impact of an incursion, or prepare for and manage a response in the event than an incursion occurs. The GIA involves a number of terrestrial sectors

[4] Further information available at: https://marinepests.nz/

[5] http://www.aplusaquaculture.nz/#frameworks
https://www.mpi.govt.nz/dmsdocument/13293-aquaculture-biosecurity-handbook-assisting-new-zealands-commercial-and-non-commercial-aquaculture-to-minimise-on-farm-biosecurity-risk/sitemap

(e.g. dairy farming, commercial plantation forestry, etc.), however, there are no marine sectors as signatories at this stage.

3.2. Risk mitigation options

Management of HMOs after they have established in a location is often challenging and expensive. As such, a key priority for effective marine biosecurity must be to prevent the initial introduction and subsequent domestic spread of harmful organisms. As discussed above, this primarily involves the management of vectors and associated risk mechanisms, with numerous existing and in-development treatment tools and risk mitigation measures available. These are largely focused on the risk from vessel movements, with a particular focus on the risk from hull biofouling. Treatment tools include both land-based (e.g. manual removal with brushes and scrapers or mechanical removal via water-blasting) and in-water tools (e.g. rotary brush systems, high-pressure water jets, and shrouding technologies such as wrapping). A comprehensive overview of risk mitigation options for the six main sectoral pathways in New Zealand[6] is provided in Inglis *et al.* (2013).

3.2.1. Pathway-based vs species-based management approaches

The most realistic ambition for biosecurity management in the marine environment is risk reduction, as total prevention/negation of risk is seldom feasible. Management options will need to be assessed on a case-by-case basis, as they will depend on the nature of transfer pathways associated with existing and new types of activities, the pre-existing level of risk in the Waikato region, and the region's ever-changing profile in terms of existing high-risk species. Previously, the focus of marine biosecurity management has been largely species-specific[7]. However, it is now generally acknowledged that a pathway-based approach best addresses marine biosecurity risk to a region or to New Zealand as a whole. Rather than focus on certain species, pathway-based management measures are inclusive of all associated species, irrespective of their status as HMOs. This approach also recognises that the impacts of known HMOs may vary considerably over time and among locations, and that HMOs with no designated or recognised status may emerge as problem organisms in future years. Additionally, the risk profile for a region is likely to change over time as species distributions change within New Zealand, or as new risk species from overseas source regions arrive and establish (Forrest *et al.* 2015). Anthropogenic influences (e.g. coastal hardening through urbanisation, increased sedimentation and nutrient run-off from terrestrial sources) and associated degradation of coastal margins may also make these areas more susceptible to invasion through time.

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[6] Pathways assessed included: maritime transport, mining and exploration, commercial fishing, aquaculture, recreation and sport, and research and education.

[7] An example of this is reflected in the wording of older mussel farm resource consent conditions, whereby mussel spat is required to be sourced from farms or spat catching areas where there is no *Undaria pinnatifida*.

3.2.2. Regional pathway management plans

Amendments to the Biosecurity Act in 2012 allowed for the creation of regional pathway management plans to reduce the spread of pests and diseases that are already present in New Zealand, but not yet widespread. Several regional council authorities around New Zealand have now developed or are developing plans that include practical measures to reduce the risks of transport of marine pests. Environment Southland's 'Fiordland Marine Regional Pathway Plan' was the first of its kind in New Zealand and aims to greatly reduce the risk of marine pests being carried into the Fiordland Marine Area (FMA) on local and visiting vessels (Environment Southland 2017). The plan sets out a number of rules and standards that must be met by all vessels entering within one nautical mile of the landward boundary of the FMA and requires vessel operators to obtain a Fiordland Clean Vessel Pass. The pass is applied for online by providing information regarding passage plans as well as hull antifouling and maintenance history. Obtaining the pass includes agreeing to abide by the following standards:

- Clean hull standard: The hull and niche areas have no more than a slime layer and goose barnacles.
- Clean gear standard: All marine gear and equipment on the vessel (including any equipment to establish new moorings) is visibly clean, free of fouling, free of sediment and preferably dry.
- Residual seawater standard: All on-board residual seawater has been treated or is visibly clean and free of sediment.
- Records: The owner or person in charge of a vessel entering the area which the plan applies to must keep records of the actions taken to meet the clean hull, clean gear and residual water standards and provide those records to an authorised person on request.

The Fiordland pathway plan has been operational since April 2017 and initial feedback from stakeholders has been largely positive with the rationale and process for implementation appearing to have been clearly communicated.

While focused on the same vector risks, Northland Regional Council (NRC) have taken a slightly different approach in the development of their 'Northland Regional Pest and Marine Pathway Management Plan' (Northland Regional Council 2018). The Northland plan sets out an achievement standard for biofouling on boat hulls, both entering Northland waters and moving between 18 'designated places' (several harbours, marine reserves and popular anchorages). The achievement standard is that the fouling on the hull and niche areas of the craft does not exceed 'light fouling'. 'Light fouling' is defined as: small patches (up to 100 mm in diameter) of visible fouling totalling less than 5% of the hull and niche areas. A slime layer and/or any species of barnacles are deemed allowable fouling. Breach of the achievement standard is deemed an offence under the Biosecurity Act and incurs a fine of up to $5,000.

Initial feedback on the draft plan raised the issue that the achievement standard was very difficult for boat owners to assess, particularly in remote areas where there are no haul-out facilities. Concerns were also raised regarding the use of 'light fouling' as the basis for the rule without also including sanctioned methods for achieving this standard. In response, NRC have incorporated a voluntary antifouling declaration, which is issued by the Council if the vessel has had antifouling paint applied according to the manufacturer's instructions within the preceding 12 months. Owners of vessels that hold a declaration will not be prosecuted if macrofouling or filamentous algae does not exceed 15% of the visible hull surface, but instead may be issued with a Notice of Direction to get their hull cleaned. This means that holders of an antifouling declaration can be certain that if their hull marginally exceeds the 'light fouling' achievement standard, they will not be prosecuted. The Council have staff whose role it is to check compliance with the above standards and follow up with vessels with regards to any infringements.

3.2.3. Regional pest management plans

Regional councils are able to put rules and conditions in their regional pest management plans (RPMP) to exclude or eradicate particular species that are established elsewhere in New Zealand but have not reached the region; or to progressively contain, or control particular species that are in the region. This would enable the council to take immediate action should a new pest come into the region or to contain species that are already present. In addition, councils can also specify rules and conditions that will contribute to pathway/vector management within their regions as well as supporting pathway management beyond their regions. For example, RPMPs could set out rules to manage biofouling on vessels and moveable structures within their waters. Both Marlborough District Council and Bay of Plenty Regional Council have specified acceptable levels of hull fouling in their current or proposed RPMPs.

3.2.4. Small scale management programmes

Another tool that can be used is a small scale management programme (SSMP). This approach is often used if a particular species is not named as a pest in the RPMP. SSMPs can be used for relatively low cost and short-term management of pests, where it is believed the organism can be eradicated or controlled effectively by small-scale measures within 3 years of the measures starting because its distribution is limited. This approach has been used by the three councils at the top of the South Island to eradicate/control the Mediterranean fanworm (*Sabella spallanzanii*) in these regions. In addition, Bay of Plenty Regional Council has SSMPs in place for both Mediterranean fanworm and the clubbed tunicate (*Styela clava*).

3.2.5. Development of activity-specific biosecurity management plans

Comprehensive construction and operational details of an activity may not be known at the time of an activity occurring or a resource consent application. As such, prescriptive response requirements or consent conditions can lead to unworkable requirements, and lead to future difficulties if the regional situation changes. Therefore, we advocate an approach whereby consent conditions will require the development of an approved Biosecurity Management Plan (BMP) for the associated activity, with the detail specified in that plan once operational details are known or if operational details change.

We consider wording of the following general nature provides a useful baseline from which activity-specific consent conditions can be developed:

- At least one month prior to the activity commencing, the consent holder shall provide a BMP to the Consent Authority.
- The purpose of the BMP shall be to specify how the risk of a biosecurity incursion, or exacerbation of risk, is to be reduced to the greatest extent practicable.
- The BMP shall include, but not be limited to, the following:
    - a description of the activity and the attributes that affect risk
    - an assessment of key biosecurity risks from activities authorised by the consent, and methods used to minimise those risks to the greatest extent practicable.
    - record-keeping and documentation of all mitigation undertaken.
- The BMP shall be prepared by a suitably qualified person who is experienced in managing the risk of biosecurity incursions and who shall be appointed by the consent holder.
- The BMP shall be approved in writing by the Consent Authority Manager prior to the first commencement of the activity authorised by the consent and the consent holder shall undertake all activities authorised by the consent in accordance with the approved BMP.
- Any amendment of the BMP shall be approved in writing by the Consent Authority Manager before any amendments are implemented and the consent holder shall undertake all activities authorised by the consent in accordance with the amended BMP.

Where appropriate, any relevant standards, guidelines or codes of practice that can be applied to address biosecurity risks to an acceptable level can be referred to as specific requirements in the production of the BMP. In addition, appropriate requirements regarding review, for instance to update with regards to new biosecurity guidance or requirements, and auditing of this document will greatly aid in its effectiveness.

With reference to already established, ongoing activities, it can be difficult to amend consent wording to add biosecurity management conditions later. For example, most active marine farming consents in the Waikato region do not currently require any form of biosecurity management. Some farm consents in the region expire in 2025, however others are not up for renewal until 2041, resulting in a potentially long delay before formal biosecurity management for these sites can be required.

The proposed national environment standard for marine aquaculture (NES: Marine aquaculture) seeks to address these timing issues[8]. A NES is established under the Resource Management Act 1991 and sets national rules that replace regional council rules. The proposed NES: Marine aquaculture seeks to:

- provide a more efficient and certain consent process for managing existing marine farms within environmental limits
- implement a nationally-consistent framework for biosecurity management on all marine farms.

Consultation with stakeholders was carried out during 2017, with the NES: Marine aquaculture likely to become operative in 2020. It is proposed that all marine farm consents be reviewed by 2025 to include BMPs. The NES: Marine aquaculture is expected to include some guidance material on the preparation of marine farm BMPs.

[8] See: https://www.mpi.govt.nz/news-and-resources/consultations/proposed-national-environmental-standard-for-marine-aquaculture/submissions/

4. BIOSECURITY RISKS FROM ACTIVITIES/STRESSORS WITHIN THE WAIKATO COASTAL MARINE AREA

4.1. Framework for risk identification

A wide range of coastal activities/stressors occur with WRC's jurisdiction, all of which have unique risks and implications with regards to marine biosecurity. In order to implement appropriate management responses, the context and magnitude of these risks need to be understood. For all human activities that affect the CMA, and which are under the control of WRC, the common biosecurity-related questions that need to be considered include:

- **Origin of risk:** Whether the activity/stressor introduces biosecurity risks that arise from outside the Waikato CMA, and in particular whether the origin is from:
    - international source regions (e.g. movement to New Zealand of specialist equipment used for dredging or seabed mining); or
    - other regions of New Zealand, in particular those known to have recognised high-risk HMOs that are not present in the Waikato CMA.

  Special considerations and elevated risks arise in the case of international transfers.
- **Novelty of risk:** Whether the activity/stressor is likely to lead to novel biosecurity risks or represents an increment to risks from existing activities in the Waikato CMA. For instance, the activity involves vector pathways that do not already occur as a result of other human activities in the region.
- **Magnitude of risk:** The likely importance of the activity/stressor in the context of other controlled and uncontrolled activities that give rise to biosecurity risk in the Waikato CMA. For instance, the activity involves pathways that are considerably more frequent than other human-mediated pathways unrelated to the activity/stressor, or pathways that lead to HMO introduction risk that is considerably greater than that posed by natural dispersal from existing source populations.

In the following sections (Sections 5-9), the above framework for risk identification has been applied to 13 specific activities or stressors[9] that WRC has responsibility for under the Resource Management Act and Biosecurity Act. This includes an explanation of the processes involved, the potential impacts that may arise and the degree of risk involved for each activity/stressor. Activities/stressors have been grouped based on activity type. Due to similarities between some activities there may be some degree of overlap in terms of common background material and themes; however, where possible we refer the reader to relevant previous sections of the text.

[9] The activities/stressors addressed in this report were agreed on with WRC as part of an earlier scoping exercise and represent a priority in terms of marine biosecurity risk to the region.

5. BIOSECURITY RISKS AND MITIGATION FROM BOATING ACTIVITIES

The movement of vessels (of all sizes) and transportable structures (e.g. oil platforms, finfish farming sea-cages) is recognised as one of the most significant vectors for the translocation of HMOs to and within New Zealand coastal waters. While international vessel arrivals are generally the source of initial introductions, the domestic shipping, boating and aquaculture networks provide a mechanism for the transport of HMOs among New Zealand's coastal locations (Hayden *et al.* 2009). Hull biofouling and ballast water discharges (discussed in Section 2.3.1) are widely regarded as key mechanisms for HMO spread associated with the movements of vessels or structures (Hewitt *et al.* 2004; Inglis *et al.* 2010a). Similarly, movements of gear or equipment associated with commercial or recreational boating activities is also reasonably well understood for some sectors (see Section 2.3.2). In addition, there are several additional vectors and mechanisms of spread where HMO transfer risk is recognised but less well understood. These include:

- movements of small craft like trailered boats and kayaks
- discharge of bilge water (see Section 2.3.1).

An overview of the biosecurity risks associated with the three main groups of vessels (recreational vessels, small commercial vessels and large commercial vessels) operating within the Waikato CMA is provided below. We consider '*intra*-regional' vectors (i.e. those movements confined to the Waikato CMA region) and also '*inter*-regional' vectors that connect Waikato with other regions (including pathways both to and from the Waikato CMA). We have not attempted to be comprehensive in terms of the full range of vectors or region-specific patterns of activity, as to do so was beyond the scope of this project. As there is a reasonable level of general knowledge about relative biosecurity risks from the common vector types and risk mechanisms, we consider that the 'high level' approach we take below should address the most important issues.

Options for mitigation of particular sources of biosecurity risk are provided. Where relevant, we describe measures that MPI is undertaking to manage biosecurity risks from international vectors, as this provides a context for considering any additional regional management approaches. Information regarding potential treatment methods for heavily fouled vessels is provided in a number of technical reports (e.g. Piola & Forrest 2009; Inglis *et al.* 2013; Forrest & Floerl 2018). The preferred treatment option is to remove the vessel from the water and clean it on land, however it is recognised that there may be many instances where a vessel owner is unable or unwilling to comply with a haul-out request. Haul-out and cleaning of a vessel may also be deemed to be not be possible (e.g. insufficient resources) or timely (e.g. a new pest species is discovered on a vessel and must be removed urgently). In those instances, the following in-water treatment methods have been identified:

- manual removal, including hand-picking and cleaning with scrapers, brushes, and in the case of more fragile fouling release coatings, sponges or soft cloths
- mechanical removal (e.g. rotating brush technologies, contactless mechanical systems, high-pressure water jet systems, cavitational water jet systems and vacuum systems)
- surface treatments (e.g. heat treatments or ultrasonic treatments)
- in-water 'wrapping' of the vessel hull, including the addition of freshwater or eco-friendly chemicals such as acetic acid or bleach to the encapsulated water to accelerate mortality of target pests.

Most regional councils have rules restricting in-water cleaning of vessels in their regional plans, which in turn are based on regulations stipulated in the Resource Management (Marine Pollution) Regulations (1998) and the Australian and New Zealand Environment and Conservation Council (ANZECC) water quality guidelines. This matter is discussed further in Section 5.1.2. A summary of biosecurity risks associated with boating activities is provided at the end of the section (Table 3).

5.1. Recreational vessels

Recreational vessels include sailing/motor yachts and launches as well as trailered craft of many types (e.g. jet skis, kayaks, canoes). Recreational vessels that move between New Zealand's coastal regions mostly comprise sailing and motor yachts and launches that are permanently moored in the water. These vessels typically have a length of 8–20 m but superyachts can reach > 100 m. The number of recreational vessels based in New Zealand is not known precisely as there is no required registration of non-commercial craft. However, the 2018 Maritime New Zealand survey (Griffiths *et al.* 2018) reported that approximately 1.5 million adult New Zealanders are involved[10] in recreational boating. A 2011 survey estimated that around 600,000 recreational craft are owned around New Zealand, of which 10% are permanently moored recreational motor and sailing yachts and launches (Floerl *et al.* 2015). The Waikato region has the fourth highest population of recreational boaters in New Zealand (9% of the general population; Griffiths et al. 2018).

Recreational vessels can pose a significant biosecurity risk as they operate at a range of geographical scales (i.e. local, region and international) and their movement is largely unregulated. In addition, other risk factors include them being typically slow moving, numerous, remain idle for long periods, and frequenting high-value areas (e.g. marine reserves) as well as transport hubs (e.g. marinas). This vessel class also has a high potential for biofouling in niche and hull areas due to their association with

[10] 'Involved' is defined as either owning a recreational vessel, in charge of or skippering a recreational vessel (but do not own), or spending time on a recreational vessel (but do not own or skipper it).

fouled swing moorings or marina pontoons. Movements of recreational vessels are often a key factor in the regional spread of marine pests (Piola & Forrest 2009).

Several previous reports have considered the biosecurity implications of the movement of recreational vessels in New Zealand (e.g. Hayden *et al.* 2009; Piola & Forrest 2009; Floerl *et al.* 2015). We provide a high-level summary of the information contained in these documents, with readers directed to the source literature for a more comprehensive assessment.

There are two broad sources of marine biosecurity risk that are associated with recreational vessel activities:

1. Risks associated with the movement of the vessel itself, including overland movements, as well as associated equipment (e.g. anchors, fishing gear, shellfish dredges).
2. Risks associated with the discharge of material through maintenance or cleaning of the vessel.

An overview of each risk type, as well as potential options for mitigation of associated risks, is provided below. Mitigation options proposed are largely based on those outlined in Piola and Forrest (2009) and Floerl *et al.* (2015).

5.1.1. Movement of the vessel and associated equipment

Risk mechanisms for recreational vessels are the same for vessel movements in general (see Section 2.3.1), aside from ballast water risks which are not directly relevant given the comparatively small size of vessels in this group. Risk mechanisms are also largely the same for equipment and gear movements in general, including transfer through entrained sediments, entrained water and/or associated fouling or entanglement (see Section 2.3.2).

Although moored vessels that reside permanently in-water are considered to be of higher importance, overland movements of trailered vessels (e.g. small yachts, jet skis, kayaks) may also pose a biosecurity risk (Hayden *et al.* 2009). This is particularly the case if the vessel is moved between localities that are geographically separated by land, where HMOs would not likely be spread through natural dispersal mechanisms alone (i.e. via water currents). Marine organisms can be transported through sediments and weeds associated with anchors, bilge water, nets, ropes and floats (Dodgshun *et al.* 2007). The risk from hull fouling is likely to be considerably reduced due to time spent out of the water. However, a study in Canada illustrated the potential for the invasive sea squirt *Styela clava* to survive 48 hours of air exposure with only 10-11% mortality (Darbyson *et al.* 2009). Boat trailers themselves also pose a risk, in particular for the spread of marine weeds, with boat wash down areas only considered to be partially successful at removal (estimated at ~70% effective in Tauranga; EBOP 2008). It is believed the spread of freshwater macrophytes between

New Zealand lakes was due to the movement of trailered boats (Johnstone *et al.* 1985).

Origin of risk: Depending on the origin and length of time spent out of the region, any vessel entering the Waikato CMA may introduce biosecurity risks. The direct risk from international vessels is low, as the Waikato region does not have any marinas designated as 'places of first arrival' (approved to receive international vessels[11]). Recreational vessels travelling domestically also pose a risk, with sailing and motor yachts known to undergo local, regional and long-distance domestic trips and voyages. An earlier questionnaire-based study found the marinas within Coromandel Harbour, Thames, and Whitianga receive domestic vessels from a wide range of locations (Hayden *et al.* 2009). In general, there were more vessels arriving from regions relatively nearby (e.g. Hauraki Gulf, Northland, Bay of Plenty). However, Whitianga was shown to receive vessels from the top of the South Island (Picton and Nelson) and Lyttelton.

Novelty of risk: Risks posed by the movement of recreational vessels will be greatest at marinas, boat ramps, areas containing swing moorings and areas of high recreation value where an increased number of vessels are likely to visit. As recreational vessel numbers are predicted to increase annually, there is potential for the level of risk to increase over time. However, unless their potential range increases (e.g. direct international arrivals, new marinas, subdivisions with moorings, etc.), they are not likely to lead to novel biosecurity risks. In the Waikato region, movements of trailered craft between the east and west coast of the Coromandel Peninsula are likely to be one of the key situations in which spread of HMOs by small craft and/or their trailers is the greatest risk.

Magnitude of risk: The magnitude of risk for HMO incursions associated with the movement of recreational vessels can be considered comparatively high in relation to other vessel types. Maintenance practices and the often-sporadic patterns of use of recreational vessels make them arguably a greater biosecurity risk than commercial vessels. Similarly, many recreational craft (especially yachts) have a relatively slow operating speed (5–10 knots) compared to commercial vessels (≥ 15 knots). Slow-moving vessels can become heavily fouled, and a slow voyage speed is generally considered to favour the survival of associated biofouling species. Compared to larger commercial vessels, recreational vessels are also more likely to visit and spend time near to high-value areas (e.g. marine reserves, aquaculture facilities). Their association with 'transport hubs' such as marinas, which are often geographically close to commercial shipping ports, also increases the likelihood of colonisation by high-risk HMOs. Trailered vessels used in the marine environment pose less of a

[11] The 'places of first arrival' approved to receive all types of recreational vessels are: Opua, Marsden Point, Picton and Lyttelton. Auckland Viaduct and Silo Marina are only approved for superyachts (> 24 m in length and professionally crewed). Arriving elsewhere is only permitted if there is an emergency, or if the vessel operator has applied for and received prior approval (and biosecurity conditions) from MPI to arrive at another location.

biosecurity risk if they are washed often with fresh water and dried between immersions, or if they are used by fishers within a limited range of coastal areas.

Mitigation options

Mitigation options for biosecurity risks related to the movement of recreational vessels could include:

1. Restrict movements of vessels that do not meet certain thresholds with regards to hull antifouling and maintenance, as well as requirement to adhere to guidelines regarding gear and residual sea water.

Movement controls could be considered for vessels with high levels of fouling, particularly if they are seeking to visit high-value areas (Sinner *et al.* 2013). This would require the development of a regional pathway management plan under the Biosecurity Act (see Section 3.2.2). In addition, restrictions on entry to specific locations could be imposed, for example, restricting berthage at marinas unless adequate levels of hull fouling maintenance can be proven (see Section 7.1.2).

2. Encourage owners of permanently moored vessels to follow good maintenance practices (e.g. adhere to the 'Clean Below? Good to Go' message).

Biosecurity risks tend to be most significant on poorly maintained vessels. As such, vessel vector risks can be mitigated via good maintenance practices as follows:

- ensure all vessels have up-to-date and vessel-appropriate antifouling systems; record paint types used and expected service life
- regularly inspect hulls for conspicuous fouling or notifiable pests; careful attention should be given to niche areas (e.g. bottom of keel, pipe intake/outlets, rubbers, hard-stand support strips) as these are particularly prone to biofouling
- wash or purge water and debris from decks and bilge before leaving one area for another
- become familiar with MPI's 'New Zealand's Marine Pest Identification Guide'
- report suspected marine pest or pathogen detections to the MPI Exotic Pest and Disease Hotline (0800 80 99 66).

The single most effective way of preventing or restricting vessel infection by fouling organisms is the regular application and maintenance of hull antifouling. Risk analysis studies have determined that the age of antifouling paint on recreational vessels such as yachts can be a key factor determining the presence of hull fouling organisms (Floerl *et al.* 2005b). The International Maritime Organization (IMO) provides recommendations for different antifouling coating systems to suit different craft and activities (IMO 2012). Specific considerations include:

- planned periods between hauling/drying out or maintenance—to make sure the coating is effective for that time period
- craft speed and patterns of use—biofouling can rapidly accumulate when craft are stationary or inactive in port or coastal waters
- construction material (steel, wood, aluminium, etc.)—systems are specific for different hull materials
- location to be applied on the craft—different coating types may be required for different parts of the hull or structure, such as around the propeller shaft or rudders, due to water flow conditions.

Further information regarding best practice for antifouling use is provided in a number of technical reports (Piola & Forrest 2009; DOE/MPI 2015; Forrest & Floerl 2018).

Good vessel maintenance practices are best encouraged through continuation of education/awareness campaigns in the region. For example, ongoing promotion of the Top of the North Marine Biosecurity Partnership's 'Clean Below? Good to Go' campaign regarding acceptable levels of hull fouling for vessels travelling to an area other than their home port.

3. Encourage owners of trailered vessels to follow good maintenance practices.

Simple measures are available to reduce biosecurity risks from trailered vessels. Trailered boats are addressed by MPI as part of their communications programme, which encourages people to undertake the following actions before moving their boat and trailer among different locations:

- rinse down boats, trailers and all gear thoroughly with fresh water
- remove any debris such as weeds, crabs, and barnacles and check the anchor well (as weeds and other organisms are often brought up on the anchor and chain)
- drain or thoroughly rinse areas where seawater might pool
- where possible, allow to air dry for several days before using in a new location.

These same cleaning actions could be applied to any other small personal water craft and could include, where feasible, methods using hot water, detergents or other cleaning agents. For example, these types of cleaning measures were considered for kayaks and dive gear being moved into the Fiordland Marine Area (Sinner *et al.* 2009). Because trailered craft are more easily inspected and cleaned, it would be reasonable to expect a higher level of maintenance (e.g. no more than a slime layer) especially for craft being launched into areas of special value.

Uptake of these practices could be encouraged through greater availability of wash-down facilities, and targeted education/awareness campaigns. WRC could adopt a communications approach for the Waikato region in conjunction with MPI, which could include signage at boat ramps as a means of getting the message out.

4. Encourage best practice with regards to cleaning of equipment and gear.

Good practice generally entails thoroughly drying gear before it is returned to the marine environment, possibly preceded by washing with fresh water. Codes of practice could be developed and promoted for all pathways to describe good practice for the management of marine gear and equipment. This could include, for example, washing and/or treatment of all gear prior to deployment in a new area, methods for defouling, containment of defouling where any macrofouling exists, reporting of unfamiliar organisms, and taking extra precautions when risks are particularly high (e.g. before visiting high-value areas or after visiting areas where HMOs not present in the Waikato CMA are known to be established). As with trailered craft, to maximise uptake, any such scheme should be accompanied by a targeted education/awareness campaign.

5.1.2. Discharge of material through cleaning or maintenance

In-water cleaning of vessels is discouraged under WRC's current Coastal Plan, although this is primarily aimed at preventing the discharge of contaminants. The region lacks suitable facilities for vessel cleaning, with owners often using the hard stand in Coromandel Harbour to clean their vessel hulls with associated biofouling going back into the water. Similarly, a recent survey of recreational boaters across the top of the South Island revealed that more than half clean their vessel hulls in-water, of which about one third clean 'out of sight' in pristine coastal areas like the Abel Tasman National Park coastline and the outer Marlborough Sounds (Forrest 2016). These cleaning practices are likely leading to potentially harmful organisms being dislodged to the surrounding environment, which may contribute to the establishment of marine pests in these areas (Hopkins *et al.* 2011a). In addition, the likely incomplete removal of biofouling, due to a rushed or incomplete in-water clean, may greatly increase the rate at which hulls subsequently become recolonised (Floerl *et al.* 2005a).

Origin of risk: The geographic origin of biofouling organisms on recreational vessels contributes to their biosecurity risk. In-water cleaning of a vessel, and the associated discharge of materials, has the potential to introduce biosecurity risks from outside the region depending on where the vessel has recently spent time. This is especially relevant if the vessel has spent extended periods of time overseas or in another region, particularly if that location has established populations of HMOs not present in the Waikato CMA. If all biofouling was acquired in the same location where in-water cleaning takes place, cleaning may not pose a biosecurity risk as all biofouling species on the vessel or movable structure are already present in that area (DOE/MPI 2015).

Novelty of risk: In-water cleaning of recreational vessels within the Waikato CMA will not necessarily lead to novel biosecurity risks to the region. Discharge of biofouling communities to the seabed is a common occurrence in other sectors, for example, grading of mussel crop lines as part of standard operating procedures results in the removal of considerable amounts of biofouling material. Any biofouling organisms designated as Unwanted Organisms under the Biosecurity Act (e.g. *Undaria pinnatifida*, *Sabella spallanzanii*, and *Styela clava*) that are removed from the lines through this process should be disposed of at landfill. However, it is likely that these organisms are being discharged to the seabed as part of the general biofouling community. It is recognised that in-water cleaning of recreational vessels may lead to biosecurity risks at locations within the Waikato CMA where similar risks don't presently occur (i.e. at potentially isolated mooring locations).

Magnitude of risk: As discussed above, vessels cleaned in the place where they predominantly reside can be considered relatively low biosecurity risk (Morrisey *et al.* 2013). The magnitude of biosecurity risk to the region will depend on the number of vessels undertaking in-water cleaning and the frequency with which this occurs. In addition, risk to a specific location will be influenced by the possibility of cleaning-related disturbance initiating spawning in reproductively mature biofouling, as well as the likelihood of potentially harmful species in the material establishing on the seabed or re-attaching to nearby artificial structures.

Mitigation options

Mitigation options for biosecurity risks related to the discharge of material through cleaning and maintenance of recreational vessels could include:

1. Prohibit in-water cleaning of all vessels.

Recreational boaters undertaking in-water cleaning are likely in breach of current regional or local requirements, which generally prohibit in-water cleaning under the RMA. One option is to maintain and enforce the current status.

2. Require vessel operators follow best practice for antifouling and vessel cleaning.

Advice on best practice for vessel antifouling, as well as a decision tree for assessing and managing biosecurity risks associated with in-water cleaning, are provided in the revised Anti-fouling and In-water Cleaning Guidelines (DOE/MPI 2015; see Section 3.1.2). The guidelines seek to mitigate risks associated with the release of antifouling contaminants and biofouling organisms during cleaning. However, they defer the definition of thresholds for acceptable vs unacceptable risk to local jurisdictions and associated environmental regulations. It has been identified that there is a lack of supporting detail and context necessary for regional implementation, for instance, how councils should distinguish between local, domestic and international biofouling. Accordingly, there appears to have been very little uptake of the guidelines at the regional level, and in some case a lack of awareness that the revised guidance even exists. Extensive discussion of this matter is provided in technical reports recently commissioned by MPI and TDC (Morrisey *et al.* 2013; Forrest & Floerl 2018); the reader is directed to this source material for further detail.

5.2. Small commercial vessels

A range of small commercial vessels (SCV) operate in New Zealand's waters. These include service vessels, such as tugs, pilot boats, local ferries and water taxis; patrol vessels; offshore support vessels; inshore fishing boats; cable laying ships; as well as tourist and charter vessels (e.g. for diving, fishing), etc. These non-trading vessels often work locally, within the region they are domiciled, but may make longer distance voyages to other New Zealand locations (Inglis *et al.* 2013). They are generally permanently moored in-water; however, some smaller vessels may be trailered. The number of SCV operating in the Waikato CMA is difficult to quantify, particularly as vessels based in the Auckland region often move between the two areas. The Firth of Thames and southern Hauraki Gulf is an important commercial fishing area, with the main target species being snapper, kahawai and flatfish. Aquaculture also represents one of the largest industries in the Firth of Thames region, with a high number of associated vessels (see Section 6).

The biosecurity risks associated with SCV are expected to be similar to recreational vessels operating in the Waikato CMA. One distinction is that SCV are likely to be more geographically constrained, generally remaining relatively localised in their movements. However, the consistent nature of these movements will influence risk with regards to transport of HMOs. For example, these vessels make repetitive voyages between transport hubs such as marinas and commercial wharves[12] and marine farms, charter fishing-spots, water-taxis stops, etc. Vessel undertaking particular activities on board (e.g. harvesting aquaculture stock, bringing on fishing gear) or visiting the region for specific one-off events (e.g. anchor installation at a marine farm, dredging activities) may represent a higher level of biosecurity risk. Particular attention is needed for slow-moving commercial vessels or vessels that travel infrequently from port-to-port (e.g. barges, dredges, derelict or decommissioned vessels) since these are likely to constitute the largest risk of spreading biofouling organisms. The incursions of the sea squirt *Didemnum vexillum* and of the fanworm *Sabella spallanzanii* have been associated with the movement of poorly maintained barges (Floerl *et al.* 2015).

The biosecurity implications of the movement of SCV in New Zealand has been assessed in previous technical reports (e.g. Hayden *et al.* 2009; Bell *et al.* 2011). We

[12] There are commercial wharves located at Coromandel Township, Thames, Whitianga and Whangamata. These are mainly used by SCV associated with the aquaculture and commercial fishing industries, and passenger ferries.

provide a high-level summary of the information contained in these documents, with readers directed to the source literature for a more comprehensive assessment.

As with recreational vessels, there are two broad sources of marine biosecurity risk that are associated with SCV activities:

1. Risks associated with the movement of the vessel itself, as well as associated equipment (e.g. anchors, fishing gear).
2. Risks associated with the discharge of material through maintenance or cleaning of the vessel.

An overview of each risk type, as well as potential options for mitigation of associated risks, is provided below.

5.2.1. Movement of the vessel and associated equipment

Risk mechanisms for SCV are the same for vessel movements in general (see Section 2.3.1). Although not common, some SCV have the capability to take on ballast water (e.g. fishing vessels with anti-roll tanks). Risk mechanisms are also largely the same for equipment and gear movements in general, including transfer through entrained sediments, entrained water and/or associated fouling or entanglement (see Section 2.3.2). The risks associated with trailered vessels are expected to be the same as for recreational vessels (see Section 5.1.1) and as such are not discussed further here.

Origin of risk: Vessels entering the Waikato CMA from other regions domestically, or from outside New Zealand, may introduce biosecurity risks depending on their origin and length of time spent out of the region. The direct risk from international vessels is low as the only designated 'place of first arrival' for commercial vessels in the Waikato region is the Taharoa offshore buoy. This terminal is only visited by larger bulk cargo carriers (see Section 5.3). Vessels that have spent time near the shipping ports in Auckland and Tauranga could be expected to pose the most risk.

Novelty of risk: The majority of SCV operating within the Waikato CMA are expected to be local vessels, which are not expected to lead to novel biosecurity risks to the region. Exceptions exist with vessels that travel regularly between Auckland and the Coromandel region (e.g. the ferry service operating out of Hannaford's Wharf, some aquaculture vessels). There is potential for the level of risk to increase over time if more vessels begin to operate out of the region. However, unless their potential range increases (e.g. direct international arrivals, new marinas, subdivisions with moorings, etc.) this is likely to only represent an incremental increase in biosecurity risk from existing activities.

Magnitude of risk: The magnitude of risk for HMO incursions associated with the movement of SCV is expected to be relatively low in relation to other vessel types.

In general, commercial vessels are better maintained than recreational vessels, making them arguably less risky with regards to biosecurity. Aside from charter vessels, they are also less likely to visit high-value areas such as marine reserves. Compared to recreational vessels, SCV are more likely to have bilge systems with associated pre-discharge treatments (e.g. in-line filters, oily water separators) which will reduce the likelihood of HMOs being viable at the time of discharge (Fletcher *et al.* 2017). Their association with 'transport hubs' such as commercial wharves may increase the likelihood of colonisation by high-risk HMOs.

Mitigation options

Mitigation options for biosecurity risks related to the movement of SCV are the same as those proposed for recreational vessels (see Section 5.1.1).

1. Restrict movements of vessels that do not meet certain thresholds with regards to hull antifouling and maintenance, as well as requirement to adhere to guidelines regarding gear and residual sea water.
2. Encourage owners of permanently moored and trailered vessels to follow good maintenance practices.
3. Encourage best practice with regards to cleaning of equipment and gear.

In addition, the following option could be considered for SCV:

4. Development of industry-specific codes of practice.

Industry-specific codes of practice could be developed that detail standard operating procedures for managing risks from hull biofouling, ballast water and entrained sediments or water (e.g. bilge water) on the vessel itself as well as associated equipment. This could be particularly appropriate if WRC identifies specific areas within the Waikato CMA that warrant special protection. An example of this is the Deed of Agreement between the cruise ship industry and Environment Southland with regard to ballast water discharge in the Fiordland Marine Area. That deed prohibits ballast water discharge within Fiordland except in event of an emergency.

5.2.2. Discharge of material through cleaning or maintenance

If SCV undertake in-water cleaning or maintenance, with associated discharge of biofouling material to the seabed, it is anticipated that biosecurity risks will be largely the same as that for recreational vessels, discussed in Section 5.1.2.

5.3. Large commercial vessels

A range of large commercial vessels (LCV) operate in New Zealand's waters. The maritime transport industry comprises the domestic movement of cargo and people by New Zealand-registered and foreign merchant shipping. It also includes movement within New Zealand of passenger vessels such as cruise ships, as well as naval vessels and those operating as part of the marine mining and exploration (see Section **Error! Reference source not found.**), and commercial fishing sectors. Approximately 800 individual vessels visit New Zealand's commercial ports each year (Hayden et al. 2009; Inglis et al. 2014), with these vessels operating across local, regional and international scales. The only commercial port within the Waikato CMA is the Taharoa Terminal, a single buoy mooring device located at the Taharoa Mine site, approximately 6 km offshore from Kawhia Harbour (Figure 4). Concentrated iron sand slurry is pumped through a pipeline to the buoy, after which it is transferred to bulk cargo ships before being exported overseas.

Figure 4. The single buoy mooring device, Taharoa Terminal, located ~6 km offshore from Kawhia Harbour on the western coast of the North Island (sourced from: Inglis et al. 2008).

The biosecurity risks associated with LCV in New Zealand are well recognised (Inglis 2001; Hayden *et al.* 2009; Inglis *et al.* 2010b). Some aspects of biosecurity risk relate to maintenance and voyage history and are very specific to the vessel contracted for the activity. For example, the amount and complexity of biofouling organisms present on the vessel is influenced by the time since the vessel was last dry-docked and had the present antifouling coating applied, and by the type (if any) of marine growth prevention systems used for internal seawater systems. For vessels arriving from overseas, voyage history will be important as it may influence the likely survival in New Zealand waters of biofouling organisms present on the vessel. If the vessel's most recent deployment was in a temperate locality that is 'climatically' similar to New Zealand, there is likely to be an increased risk that the activity region will provide a suitable recipient environment. Voyage history may also identify whether the vessel operated in localities known to harbour species of potential concern to New Zealand.

The recent operational profile of the vessel can also influence biosecurity risk. For example, vessels that remain idle for extended periods can accumulate considerable biofouling due to reduced efficacy of their antifouling coatings. As with SCV, slow-moving vessels or vessels that travel infrequently from port-to-port are likely to constitute the largest risk of spreading biofouling organisms. A vessel’s operational history can provide insight into the potential biosecurity risk and the likely mitigation effort required.

The biosecurity implications of the movement of LCV in New Zealand has been assessed in previous technical reports (e.g. Hayden *et al.* 2009; Inglis *et al.* 2010b). We provide a high-level summary of the information contained in these documents, with readers directed to the source literature for a more comprehensive assessment.

As with other vessel types, there are two broad sources of marine biosecurity risk that are associated with LCV activities:

1. Risks associated with the movement of the vessel itself, as well as associated equipment (e.g. anchors, fishing gear).
2. Risks associated with the discharge of material through maintenance or cleaning of the vessel.

An overview of each risk type, as well as potential options for mitigation of associated risks, is provided below.

5.3.1. Movement of the vessel or associated equipment

Risk mechanisms for LCV are the same for vessel movements in general (see Section 2.3.1), aside from bilge water risks which are not relevant to vessels of this size. Ballast water risks apply to merchant vessels, some cruise ships and certain types of drilling rig. Risk mechanisms are also largely the same for equipment and gear movements in general, including transfer through entrained sediments, entrained water and/or associated fouling or entanglement (see Section 2.3.2).

Origin of risk: The direct risk from international vessels is low as the only designated 'place of first arrival' for commercial vessels in the Waikato region is the Taharoa offshore buoy. This terminal is located approximately 6 km offshore from Kawhia Harbour, at ~32 m water depth, and is only visited by bulk cargo ships. There are limited domestic vessel arrivals at the buoy, generally arriving from Whangarei and travelling onward to Gisborne (14 domestic arrivals were recorded during 2000-2005; Hayden *et al.* 2009). The buoy is occasionally towed elsewhere for maintenance, which could represent a biosecurity risk depending on where the maintenance occurs and how long the buoy spends in the location. Although there are no direct international arrivals, the nearshore coastal waters of the Coromandel Peninsula do form part of a busy shipping route between the ports of Auckland and Tauranga which may expose the region to some level of biosecurity risk.

Novelty of risk: LCV operating in the Waikato CMA are not expected to lead to novel biosecurity risks to the region. There is potential for the level of risk to increase over time if more vessels of this size begin to operate out of the region. However, unless their potential range increases (e.g. new commercial ports allowing direct international arrivals) this is likely to only represent an incremental increase in biosecurity risk from existing activities.

Magnitude of risk: Biosecurity risks from LCV are expected to be low, due to the lack of suitable infrastructure and the small number of vessels of this size operating within the Waikato CMA. The Taharoa offshore buoy is one of the only areas of hard substrate available for fouling organisms arriving on large commercial ships in the region. Previous biosecurity assessments have found the majority of the non-indigenous and cryptogenic taxa present are only found within 3 km of the buoy, as such the risk from the structure appears very localised (Inglis *et al.* 2008). International vessels transiting nearby to the Waikato CMA are unlikely to pose a risk due to the recently implemented Craft Risk Management Standard (CRMS; see Section 3.1.1) governing levels of acceptable hull biofouling[13], as well as the legislation governing the discharge of ballast water (IHS/BWMC; see Section 3.1.1).

Mitigation options

Mitigation options for biosecurity risks related to the movement of LCV are the same as those proposed for small commercial vessels (see Section 5.2.1).

1. Restrict movements of vessels that do not meet certain thresholds with regards to hull antifouling and maintenance, as well as requirement to adhere to guidelines regarding gear and residual sea water.
2. Encourage vessel owners to follow good maintenance practices.
3. Encourage best practice with regards to cleaning of equipment and gear.
4. Development of industry-specific codes of practice.

In addition, the following option could be considered for LCV:

5. For activities under the control of WRC, require vessels operating in the Waikato CMA to follow an approved Biosecurity Management Plan (BMP).

While restricted to activities under the control of WRC, a requirement for LCV operating in the Waikato CMA to follow an approved BMP could be imposed. This could include both international vessels and those from outside the region. Guidance

[13] The CRMS does not eliminate risk, as not all vessels can be inspected, and some infected vessels may slip through the risk assessment process.

material regarding the development of BMPs is available online[14]. This includes specific recommendations for some sectors where vessels are expected to have unique operational profiles (e.g. cruise vessels, domestic fishing vessels, domestic navy vessels).

A BMP for a vessel should provide a description of the vessel and its attributes that affect risk, including key operational attributes (e.g. voyage speed, periods of time idle), maintenance history (including prior inspection and cleaning undertaken), and voyage history since last dry-docking and antifouling (e.g. countries visited and duration of stay). The document should also provide a description of the key sources of potential marine biosecurity risk from ballast water, sediments and biofouling. This should cover the hull, niche areas, and associated equipment, and consider both submerged and above-water surfaces.

A description of the risk mitigation measures undertaken should be provided. This should include details on any routine preventative treatment measures and their efficacy, including the age and condition of the antifouling coating, and marine growth prevention systems for sea chests and internal sea water systems. For international vessel arrivals, a description of any specific treatments for submerged and above-water surfaces that will be undertaken to address the Ballast Water Management Convention (BWMC) and Craft Risk Management Standard (CRMS) requirements prior to departure for New Zealand. These could include, for example, in-water removal of biofouling, or above-water cleaning to remove sediment. It should also provide a description of any additional risk mitigation planned during transit to New Zealand, including expected procedures for ballast water management.

The nature and extent of pre-border inspection that will be undertaken (e.g. at the overseas port of departure) should also be provided to verify compliance with BWMC and CRMS requirements. Adequate record keeping and documentation of all mitigation undertaken (i.e. prior to and during transit to New Zealand) should also be required.

5.3.2. Discharge of material from cleaning or maintenance

If LCV undertake in-water cleaning or maintenance, with associated discharge of biofouling material to the seabed, it is anticipated that biosecurity risks will be largely the same as that for recreational vessels as discussed in Section 5.1.2.

[14] https://www.mpi.govt.nz/importing/border-clearance/vessels/arrival-process-steps/biofouling/commercial-vessels/

Table 3. Summary of biosecurity risks associated with boating activities. Options for risk mitigation and likely feasibility to implement or enforce is provided. Mitigation options apply to all vessel classes unless where indicated (SCV: small commercial vessels, LCV: large commercial vessels).

Biosecurity risk	Mitigation options	Feasibility
Vessel and equipment movements	• Restrict movements of vessels that do not meet certain thresholds with regards to hull antifouling and maintenance, as well as requirement to adhere to guidelines regarding gear and residual sea water, through development of a 'regional pathway management plan'	Medium
	• Encourage vessel owners to adhere to good maintenance practices	High
	• Encourage best practice with regards to cleaning of equipment and gear	High
	• Development of industry-specific codes of practice (SCV, LCV)	High
	• For activities under the control of WRC, require vessels operating in the Waikato CMA to follow an approved Biosecurity Management Plan (LCV)	Medium
Discharge of material from cleaning and maintenance	• Prohibit in-water cleaning of vessels	High*
	• Require vessel operators follow best practice for antifouling and vessel cleaning	High

* The feasibility of such restrictions would be high, however enforcement is likely to be difficult.

6. BIOSECURITY RISKS AND MITIGATION FROM AQUACULTURE ACTIVITIES

Aquaculture in the Waikato CMA is presently dominated by mussel farming, based on 'longline' floating subtidal culture of green-lipped mussels (*Perna canaliculus*). Some oyster farming is conducted in estuaries and consists of intertidal culture of the non-indigenous Pacific oyster (*Crassostrea gigas*) on wooden racks (Forrest *et al.* 2015). Recently, new space has been designated for feed-added or 'fed' aquaculture, which is likely to be developed in the future for sea-cage finfish. Marine farming within the Waikato CMA currently occurs in five areas:

- **Wilson Bay Marine Farming Zone (WBMFZ):** 1,210 ha for mussel culture and with space allocated (90 ha) for development of fed aquaculture
- **Harbours of the western Coromandel Peninsula:** 300 ha, mostly in Coromandel and Manaia harbours, for mussel culture, some mussel spat-catching, and intertidal Pacific oyster cultivation
- **Harbours of the eastern Coromandel Peninsula:** This area includes small mussel (Port Charles and Kennedy Bay) and oyster farms (Whangapoua and Whitianga harbours)
- **West coast:** One mussel and spat-catching farm is consented in Aotea Harbour and one oyster farm in the adjacent Kawhia Harbour
- **Coromandel Marine Farming Zone (CMFZ):** 300 ha which is designated for fed aquaculture and will most likely be developed for finfish.

Aquaculture operations present several vector risks that can lead to HMOs being translocated between growing areas or regions. Farm-related vessels, equipment/gear, and stock can all harbour HMOs that 'hitch-hike' during movements among farms, or between farms and other areas (e.g. ports and marinas). In addition, aquaculture species themselves can become invasive when they escape into surrounding areas, and farm infrastructure can provide a reservoir for pests and diseases to proliferate and subsequently transfer to the wider environment (Naylor *et al.* 2001). While it is clear that marine farming can play an important role in the spread of HMOs, the industry has a strong incentive to manage risks to the extent that is feasible and affordable, as cultured species can be particularly vulnerable to adverse effects from some HMOs (Sinner *et al.* 2012).

An overview of the three main aquaculture sectors (finfish, mussel and oyster) as well as a broad overview of risk associated with other potential farmed species is provided below. In addition, options for mitigation of particular sources of biosecurity risk are also provided. Biosecurity risks associated with individual aquaculture activities are situation-specific, and may differ between activities depending on the specific farm location, farm attributes (e.g. spatial extent, stocking density/intensity) and biophysical factors (e.g. water depth, flushing characteristics) (see Forrest & Hopkins 2017). As such, specific proposals will need to be evaluated on a case-by-case basis, including evaluation of risk pathways, site-specific factors that contribute to the emergence of biosecurity problems, and development of specific mitigation strategies and emergency response plans (see Forrest *et al.* 2015). A summary of biosecurity risks associated with aquaculture activities is given at the end of the section (Table 4).

6.1. Finfish farming

There are currently no finfish farming operations in the Waikato CMA. However, as outlined above, water space (approx. 390 ha) within the Firth of Thames and southern Hauraki Gulf has been recently zoned to allow 'fed aquaculture' which incorporates finfish farming activities. The most likely species for commercialisation include yellowtail kingfish (*Seriola lalandi lalandi*), hāpuku (groper, *Polyprion oxygeneios*) and snapper (*Pagrus auratus*). Water temperatures in the region are considered too high to farm salmon. While hāpuku production is still largely at an experimental phase, there is more immediate interest from industry in farming kingfish or snapper in the Waikato region, as commercial-scale production for both these species has been trialed in the Marlborough Sounds and, for kingfish, is already established in southern Australia (Forrest *et al.* 2011; Forrest & Hopkins 2017).

Several previous reports have considered the various environmental issues associated with the development of finfish aquaculture in the Waikato region, including the associated biosecurity implications (e.g. Kelly 2008; Zeldis *et al.* 2010; Forrest *et al.* 2011). We provide a high-level summary of the information contained in these documents, with readers directed to the source literature for a more comprehensive assessment. The current work focuses on the biosecurity risks associated with sea-cage grow-out rather than issues with land-based hatchery production of stock.

There are four broad sources of marine biosecurity risk that may arise as a result of finfish farming activities:

1. Risks associated with the movement of culture-related vessels and structures (e.g. sea-cages); of particular importance is the origin of any vessels arriving from outside the Waikato CMA.
2. Risks associated with the transfer of culture-related equipment and gear, including the movement of nets or harvesting equipment between farm sites.
3. Risks associated with movement of stock, in particular the movement of juvenile fish from hatchery to grow-out sites.
4. Farm-scale risks associated with the site itself, including the farm providing a reservoir for the spread of HMOs to the environment or the farm creating environmental conditions that enhance established HMO populations.

An overview of each risk type, as well as potential options for mitigation of associated risks, is provided below. AQNZ's 'Sustainable Management Framework' (SMF) document for salmon provides up-to-date objectives and guidelines for minimising biosecurity risks common to salmon farming in New Zealand[15]. The guidelines represent industry best practice and, when implemented, should reduce risk to a level that is acceptable in light of current activities. It is expected that the principles will be broadly applicable across finfish farming in general. As such, specific mitigation options proposed below are largely based on the best practice Operational Procedures described in Appendix 2 of the SMF as well as those outlined in Forrest *et al.* (2011).

6.1.1. Vessel and structure movements

Finfish aquaculture operations utilise a range of vessel types, ranging from fish transporters to small launches and dinghies. Vessel movements typically comprise twice daily commuter vessel movements to transport staff, daily visits from a harvest barge and harvest crew vessel for approximately three months of each year, and twice weekly movements of a barge to transport fish feed and carry out other logistical work such as predator net changing (Forrest 2011). Sea-cage structures are occasionally moved between farm sites, although this is relatively infrequent, and the distances travelled are small. Risk mechanisms are the same for vessel and structure movements in general (see Section 2.3.1), aside from ballast water risks which are not directly relevant to finfish aquaculture in New Zealand given the comparatively small size of the vessels in this industry.

Origin of risk: Vessels used in day-to-day operation of a finfish farm are not likely to introduce biosecurity risks from outside the Waikato CMA. To date, vessel movements associated with finfish farming activities in other regions (e.g. Marlborough Sounds, Stewart Island) have tended to occur within rather than between growing regions (Forrest *et al.* 2007). However, it is recognised that at the time of writing there is a lack of suitable infrastructure (e.g. wharves) with regards to finfish aquaculture development in the region. Depending on requirements for certain vessels, transport of smolt or harvested stock may end up dependent on facilities outside of the region which will lead to increased inter-regional vessel traffic. Biosecurity risks can also arise from non-industry vessels performing specific tasks on farms (e.g. installation of farm anchors during the construction phase). The risks from these vessels will be dependent upon where the vessel has originated from, and whether the region of origin has established populations of HMOs not currently present within the Waikato CMA.

Novelty of risk: Future finfish farm developments within the Waikato CMA will be within two pre-determined locations, the Wilson Bay Marine Farming Zone (WBMFZ) and the Coromandel Marine Farming Zone (CMFZ). The WBMFZ already has existing

[15] http://www.aplusaquaculture.nz/#frameworks

aquaculture activities (i.e. mussel farming operations) so the development of a finfish farm in this zone is not expected to lead to novel biosecurity risks to the region with regards to vessel movements. However, the CMFZ is not operational at this point and has been primarily designated for finfish aquaculture only. It is therefore expected that farm developments in this zone will introduce novel biosecurity risk to the region in the form of new vessel traffic routes.

Magnitude of risk: Risks posed by vessels used during day-to-day operation of a finfish farm will be common to existing vectors within the region. Existing sources of biosecurity risk include international vessel arrivals into the Hauraki Gulf, and domestic vessel movements into the Waikato CMA or the immediate vicinity (e.g. recreational vessels, fishing boats, tourism operators, barges, merchant ships). The magnitude of risk associated with finfish farm-related vessel movements will depend on the scale of development, and the number of vessels operating from the farms. Considering the level of mussel aquaculture that already occurs in the area, the level of risk is expected to be relatively minor compared to other sources.

Mitigation options

Mitigation options for biosecurity risks related to the movement of culture-related vessels and structures could include:

1. Require all vessel operators to adhere to good maintenance standards.

Biosecurity risks tend to be most significant on poorly maintained vessels. As such, vessel vector risks can be mitigated via good maintenance practices (as detailed in Section 5.1.1). Note that, as well as being consistent with the SMF documents for all aquaculture sectors, these measures are also largely consistent with those being proposed for domestic vessels in general by regional authorities and MPI. The measures proposed are largely straightforward and should not unduly interfere with the normal operation of the farm vessels. A requirement for accurate records of vessel maintenance history, including antifouling systems in place and their expected service life, should be imposed.

2. Require notification of any vessel or structure movements from outside the Waikato CMA.

A recently granted resource consent for a mussel farm development in the Auckland region requires that council staff be notified 'before any vessel, structure (including pontoons), machinery or equipment to be used in marine farming activities, including barges used in the construction and/or maintenance of any marine farming structure, is brought to the marine farm from outside the Pacific Coast of the Auckland and Waikato regions'. The document also outlines the potential for an inspection for terrestrial and marine unwanted or risk species by a suitably qualified and experienced person.

3. Restrict the movement of farm-associated vessels and structures into the Waikato CMA from regions of high-risk.

There may be justification for more stringent pathway measures in certain circumstances, for instance the movement of vessels or structures into the Waikato CMA from regions that have known populations of HMOs of regional concern (i.e. not yet present in the region or certain areas of the region). A specific requirement that all farm-associated vessels entering the region adhere to national standards of hull fouling (i.e. the CRMS) could be also considered. However, as marine farms are often frequented by recreational boats (e.g. for fishing near to farm structures), any requirement that marine farmers meet stricter conditions than required for other vessels is likely to meet resistance from the industry.

6.1.2. Equipment and gear movements

Equipment or gear associated with a finfish farm (e.g. cage nets, harvesting equipment) are generally not transferred between growing regions, but movements between farms within a region do occur on an infrequent basis. Risk mechanisms are the same for equipment and gear movements in general (see Section 2.3.2). The semi-permanent nature of finfish farm equipment deployment means that, if it is transferred with associated HMOs (even if only present in small amounts or as microscopic life-stages), pest populations may subsequently grow and flourish in the recipient location (Sinner *et al.* 2012).

Origin of risk: The risk from equipment/gear movements associated with a finfish farm would be dependent upon whether the equipment/gear has been used before, and if so, where it originated from, and whether the location of origin has established HMOs populations. Due to the geographical separation between Waikato and the other regions in New Zealand with finfish farming activities (i.e. Marlborough Sounds, Banks Peninsula, Stewart Island), it is unlikely that equipment or gear previously used in other regions would be moved into the Waikato CMA.

Novelty of risk: Future finfish farm developments within the Waikato CMA are not anticipated to lead to novel biosecurity risks to the region with regards to the movement of equipment and gear. This is because risk mechanisms associated with these movements (i.e. movement of associated water and sediments, fouling, entanglement) will be common to existing vectors within the region (e.g. movement of mussel farming equipment, movement of recreational vessels).

Magnitude of risk: It is not anticipated that the movement of finfish farm-related equipment or gear will give rise to biosecurity risk that is considerably greater than existing sources of biosecurity risk in the region. Any movement of equipment or gear is likely to be regionally-restricted and will be relatively infrequent. In the context of other controlled and uncontrolled activities in the Waikato CMA, the risks posed by finfish farm-related equipment/gear movements are relatively minor.

Mitigation options

Mitigation options for biosecurity risks related to the movement of culture-related equipment and gear could include:

1. Require the use of new equipment or gear for development of new farms.

Any new finfish farm within the Waikato CMA should be developed with new gear where possible. This would negate the risk of an HMO introduction. The requirement for the use of new materials is not anticipated to be overly onerous on farm owners.

2. Require all previously-used equipment or gear to be thoroughly cleaned and treated appropriately.

If transfers of previously-used equipment or gear (i.e. harvesting equipment, net cleaning machines) from other regions are permitted, all equipment should be thoroughly cleaned, and appropriate treatments applied if necessary. The simplest treatments are washing (e.g. water-blasting) or air-drying although other options such as chemical disinfection exist. A requirement for appropriate treatment of any previously-used equipment or gear is likely to be largely straightforward and should not unduly interfere with the normal operation of the farm.

3. Require adequate record-keeping of any equipment and gear movements.

There should be a requirement for recording and reporting on equipment and gear transfers intra-regionally (i.e. among the main aquaculture areas within the Waikato region) as well as movements into the Waikato CMA. Ideally such information would be recorded consistently and, for the Waikato region, be collated by WRC.

6.1.3. Stock transfers

Finfish stock movements have the potential to transfer HMOs through the stock itself or through the water that stock are transported in (see Forrest *et al.* 2011). Depending on the source, this water may contain both juvenile (e.g. larvae, algal spores) and adult life-stages of macroscopic pests as well pathogens, parasites, or HAB species. Stock transfers are generally carried out on a regular schedule (i.e. salmon smolt in the Marlborough region are transferred to sea farms twice per year) and can occur across a range of spatial scales (e.g. from moving stock between cages within a farm, to moving stock from hatchery to grow-out facilities).

Origin of risk: Biosecurity risks will be dependent on the region from which stock are transferred and whether the region of origin has established HMOs populations not currently present within the Waikato CMA. As outlined in Forrest *et al.* (2011), it is assumed that any new finfish developments within the Waikato CMA will source stock from New Zealand hatcheries, although the importation of juvenile kingfish (1-5 grams live weight) from South Australia has previously been proposed (Diggles 2002).

Novelty of risk: As there are currently no finfish farms within the Waikato CMA, any movements of finfish stock will represent a novel pathway in terms of biosecurity for the region. In particular, the activity involves the potential for introduction of HMOs that are not likely to be transported to the Waikato CMA through other vectors (i.e. pathogens and parasites specific to finfish species).

Magnitude of risk: Movements of finfish stock into and within the Waikato CMA could pose a considerable biosecurity risk to the region. The magnitude of risk will depend on the types of potential risk organisms being transported through stock movements (i.e. pathogens and parasites specific to finfish species), the number of movements and the frequency of their occurrence, all of which combined influence HMO establishment risk to the region associated with this vector.

Mitigation options

Mitigation options for biosecurity risks associated with the movement of finfish stock could include:

1. Requirement for no transfer of stock with known (or suspected) diseases or parasites, or sourced from locations experiencing mortalities.

Operators should be required to maintain records that provide evidence for disease- and parasite-free status of transferred stocks and source areas. Ideally such information would be recorded consistently and, for the Waikato region, be collated by WRC.

2. Require finfish stock transfers adhere to all relevant regulatory or voluntary industry codes of practice.

Fish transport should responsibly and safely transfer fish, while ensuring the environment is protected against biosecurity risks. There are several regulatory and voluntary industry best practice guidelines which could be imposed to mitigate risks from international stock movements. Examples include the former Ministry of Agriculture and Fisheries' Import Health Standard for importing juvenile yellowtail kingfish from Australia, which specifies stringent biosecurity procedures for fish stock sourced from that country. These measures are expected to be highly effective at mitigating biosecurity risk. It may be appropriate to implement similar procedures for domestic fish stock transfers, depending on the level of associated risk that is determined during consent applications for specific operations.

6.1.4. Farm-scale biosecurity risks

Structures associated with finfish farms provide a three-dimensional reef habitat for colonisation by fouling organisms and associated biota, suspended above natural areas of seabed that are relatively two-dimensional. As marine farms are semi-permanent structures, populations of HMOs that establish on them can serve as a reservoir for spread to the wider environment, and to other regions, by natural and human-mediated processes. In addition, finfish farms may alter their local environment (e.g. change water or sediment quality) and create conditions that create or increase biosecurity risks. For example, nutrient enrichment may exacerbate a HAB species that is already established in the region. Lastly, finfish farms could be an incubator for disease and parasites that could spread to wild fish stocks which congregate around cages.

Origin of risk: Finfish farm developments lead to the creation of significant additional hard substratum habitats, which can provide novel habitat for biofouling organisms. While the majority of the biofouling community that inevitably accumulates on the farm is likely to be of local origin (i.e. from nearby established populations), the farm may facilitate the establishment of HMOs from outside the region through associated pathways and vectors (i.e. vessel movements, stock transfers).

Novelty of risk: The development of finfish farming in the Waikato CMA will result in increased amounts of submerged structures at the farm sites. Depending on the location of the farms, and proximity to susceptible habitats, this creation of novel habitat may facilitate the spread of HMOs through a ‘stepping stone’ effect. This will be particularly relevant for species with poor natural dispersal mechanisms. Likewise, the increase in biomass of farmed stock could favour the emergence and possible proliferation of a disease that would not otherwise have occurred. Background risk occurs as a result of already-established pest populations within the Waikato CMA (or sub-regions therein); as such, species may increase in abundance as a result of further aquaculture development, regardless of mitigation measures put in place.

Magnitude of risk: As outlined in Forrest *et al.* (2011), at the scale of an individual finfish farm, the incremental reservoir risk may be relatively unimportant. However, at full development with c. 390 ha of water space within the Waikato CMA used for finfish culture, the surface area of artificial structures (hence the propagule reservoir) will be considerably increased. The extent of increase will depend on the available surface area of farm structures (e.g. cages, anchor ropes) and their importance relative to existing structures in the region.

Mitigation options

Mitigation options for farm-scale biosecurity risks associated with the creation of novel habitat could include:

1. Require 'passive' surveillance within the farm to enable early detection of HMOs.

Alterations to the environment that may favour HMOs are likely to be highly localised. As such, 'passive' monitoring within the farm is likely to be sufficient to manage this risk. Farm personnel should become familiar with MPI's 'New Zealand's Marine Pest Identification Guide'. As for marine pests, surveillance should also be carried out to ensure early detection of the most high-risk pathogens or parasites of the proposed culture species. Surveillance could include ongoing routine health surveys of stock (including behavioural assessment), assessment of the incidence of disease, and pathology examination to determine the cause of any mortalities. Any suspected new or notifiable pests or diseases should be reported to the MPI Exotic Pest and Disease Hotline (0800 80 99 66).

2. Require control of HMO populations where feasible.

Control of established HMO populations should be attempted where feasible. From a wider environmental perspective, control of pest populations on structures will reduce propagule pressure for spread to other habitats (including other finfish farms) or other vectors (e.g. vessels). There may also be circumstances in which it is worthwhile responding to *new* high-risk species detected on a finfish farm (e.g. attempting to eradicate), but assessment of efficacy will require consideration of other sources of risk (e.g. background risk and re-infection potential). Any control or eradication programmes should involve the capture of waste material for appropriate disposal.

3. Require development of measures to control disease outbreaks.

Measures to contain and control disease outbreaks should be developed, including cleaning and disinfection of associated equipment. Where disease agents are detected, there are a number of strategies (e.g. limiting stocking density, cohort management, fallowing, applications of treatments such as vaccinations) that may be appropriate to minimise the risk of outbreaks. Records should also be kept of any treatments applied (e.g. treatment method, date, effectiveness) and numbers of stock slaughtered or disposed of. A detailed overview of these is outside the scope of the current report, however readers are directed to Forrest *et al.* (2011) for further information.

4. Require cleaning of farm infrastructure to occur on site, or if in a land-based facility, requirement for debris to be disposed of at an appropriate landfill.

Aside from marine pest control for biosecurity reasons, some level of general biofouling control will be required on finfish farms for operational reasons. Defouling infrastructure (e.g. sea-cages, accommodation blocks, feed barges) is necessary to reduce weight and drag. Any cleaning of farm infrastructure should ideally be undertaken on site. Cleaning on site ensures biofouling and sediment are released within the permitted area and helps prevent the transfer of species between areas. Where land-based cleaning is undertaken, debris should be collected and disposed of at a suitable landfill or in such a way that no viable organisms (or their reproductive material) are returned to coastal marine areas.

6.2. Mussel farming

At present, there are ~100 consented mussel farms located within the Waikato CMA. The majority of farms are located within the Thames-Coromandel District, with a single farm in Aotea Harbour on the region's west coast. These farms occupy ~1,480 ha of water space and produce ~25,000 tonnes of green-lipped mussels per year (Pambudi & Clough 2017). Several reports have considered the various environmental issues associated with mussel aquaculture, including the associated biosecurity implications (Keeley *et al.* 2009; Forrest & Fletcher 2015). We provide a high-level summary of the information contained in these documents, with readers directed to the source literature for a more comprehensive assessment.

As with finfish farming, four broad sources of marine biosecurity risk that may arise as a result of mussel farming activities have been identified:

1. Risks associated with culture-related vessel movements; of particular importance is the origin of any vessels arriving from outside the Waikato CMA.
2. Risks associated with the transfer of culture-related equipment and gear (e.g. ropes and floats) between farm sites.
3. Risks associated with movement of stock, in particular the movement of mussel spat from spat collection areas to grow-out sites.
4. Farm-scale risks associated with site itself, including the farm providing a reservoir for the spread of HMOs to the environment or the farm creating environmental conditions that enhance established HMO populations.

An overview of each risk type, as well as potential options for mitigation of associated risks, is provided below. AQNZ's 'Sustainable Management Framework' (SMF) document for green-lipped mussels provides up-to-date objectives and guidelines for minimising biosecurity risks common to mussel farming in New Zealand[16]. The guidelines represent industry best practice and, when implemented consistently and appropriately, should reduce risk to a level that is acceptable in light of current activities. As such, specific mitigation options proposed below are largely based on the best practice Operational Procedures described in Appendix 2 of the SMF.

[16] http://www.aplusaquaculture.nz/#frameworks

6.2.1. Vessel movements

Vessel movements associated with mussel farming operations may occur in relation to farm construction (e.g. screw-anchor deployment for conventional mussel longlines), farm servicing, and harvesting. Vessel types include mussel harvesters/seeding vessels, barges, and small launches (Inglis *et al.* 2010b). Risk mechanisms are the same for vessel movements in general (see Section 2.3.1), aside from ballast water risks which are not directly relevant to mussel aquaculture in New Zealand given the comparatively small size of the vessels in this industry.

Origin of risk: Most mussel industry service vessels tend to operate within a single farming region; however, inter-regional movements can occur particularly for harvesting purposes (Forrest & Blakemore 2002). As such, vessels used in the day-to-day operation of a mussel farm are not likely to introduce biosecurity risks from outside the Waikato CMA. However, biosecurity risks can arise from non-industry vessels performing specific tasks on farms (e.g. installation of farm anchors during the construction phase). The risks from these vessels will be dependent upon where the vessel has originated from, and whether the region of origin has established HMOs populations not currently present within the Waikato region.

Novelty of risk: Biosecurity risk associated with the movement of mussel farm-related vessels will be site-specific and dependent on existing activities in the location. Vessel movements associated with a mussel farm development in an already established farming zone (i.e. Wilson Bay Marine Farming Zone) will be common to the existing mussel farming operations in that area. As such, their activity is not likely to lead to novel biosecurity risks. However, any mussel farm developments in new areas, that do not presently have this form of vessel traffic, will represent a novel biosecurity risk to the region.

Magnitude of risk: Areas consented for mussel farming in the Waikato CMA are in close vicinity to domestic and international shipping routes, as well as already established populations of marine pests. Existing sources of biosecurity risk include international vessel arrivals into the Hauraki Gulf, and domestic vessel movements into the Waikato region or the immediate vicinity (e.g. recreational vessels, fishing boats, tourism operators, barges, merchant ships). Farm-related vessel movements are therefore expected to represent a relatively minor risk to the region.

Mitigation options

Mitigation options for the movement of mussel farming-related vessels are the same as those proposed for finfish farming (see Section 6.1.1).

1. Require all vessel operators to adhere to good maintenance standards.
2. Require notification of any vessel movements from outside the Waikato CMA.

3. Restrict the movement of farm-associated vessels into the Waikato CMA from regions of high-risk.

6.2.2. Equipment and gear movements

Transferring equipment and gear between farms is not particularly common but it does occur. For example, mussel ropes or floats from an existing farm could be reused as part of an additional farm development, with the potential to translocate any associated biofouling pests.

Origin of risk: The biosecurity risks posed by equipment associated with mussel farms are dependent on whether or not transfers between farms occur, and where the transfers originate from. Transfers between farms in the same farming region (i.e. within the Coromandel) are expected to pose less biosecurity risks; however, there is the potential for the development of new populations within a region through this transport mechanism (e.g. as was the case with the colonial sea squirt *Didemnum vexillum* in the Marlborough Sounds farming region). This is particularly the case for areas that may be naturally separated in terms of water current movements (e.g. the east and west coasts of the Coromandel Peninsula) whereby movements of equipment will pose a high risk to the recipient region. Similarly, transfers from other regions (particularly those with established HMOs populations not currently present within the Waikato CMA) will represent a high risk to the recipient region.

Novelty of risk: Whether the transfer of equipment and gear between farms will lead to novel biosecurity risks will depend on existing activities within the region. Due to the scale of current mussel farming operations in the region, it is likely that mussel farm-related gear and equipment is currently being transported into the Waikato CMA. That being so, any new development will represent an increment to the existing level of risk.

Magnitude of risk: In the context of other controlled and uncontrolled activities that give rise to biosecurity risk, the transfer of mussel farm equipment and gear within the same farming area (i.e. within the Firth of Thames) is not likely to pose an unacceptably high level of risk. Transfer of previously-used equipment or gear between geographically distinct areas (i.e. between the east and west coasts of the Coromandel Peninsula) and from outside the region, however, does have the potential to pose a considerably greater introduction risk. Appropriate and effective treatments are expected to mitigate this risk to a high degree.

Mitigation options

Mitigation options for the movement of mussel farming-related equipment and gear are largely the same as those proposed for finfish farming (see Section 6.1.2).

1. Require the use of new equipment or gear for development of new farms.

2. Require all previously-used equipment or gear to be thoroughly cleaned and treated appropriately.
3. Require adequate record-keeping of any equipment and gear movements.

With reference to the requirement for appropriate treatment of previously-used equipment of gear, AQNZ's SMF document for the green-lipped mussel sector includes reference to guidance provided by MPI as part of their 'Clean Boats – Living Seas' programme. The primary recommendation is that equipment or gear is not moved between regions. If this is not possible, cleaning and sterilisation by one of the following methods is recommended:

- **Remove** the item/s from the water and thoroughly air-dry. The item/s should be left out of the water for a month. Care is needed to ensure ropes and equipment are not laid out in a manner that prevents the surfaces from drying out.
- **Soak** the item/s as below:
  a. Soak in fresh water for 72 hours. If soaking ropes, fresh water should be replaced after 12 hours to ensure the water does not remain brackish.
  b. Soak the item in a 2 percent bleach/freshwater solution for a 30-minute period.
  c. Soak the item in a 2 percent Decon 90 detergent/freshwater solution for a 30-minute period.
  d. Soak the item in a 4 percent acetic acid/freshwater solution for a 10-minute period. Rinsing afterwards is option.

A requirement for appropriate treatment of any previously-used equipment or gear is likely to be largely straight-forward and should not unduly interfere with the normal operation of the farm.

6.2.3. Stock transfers

Juvenile mussel stock may be transferred out of the water among farms and regions, or from hatcheries, and there is a risk that associated HMOs will also be transferred. The Coromandel mussel farming industry mostly uses 'Kaitaia' spat, which is harvested attached to beach-cast seaweed along Northland's Ninety Mile Beach, although some spat is also sourced from Aotea Harbour on the region's west coast. The transfer of Kaitaia spat is regulated by a voluntary industry code of practice developed by the New Zealand Mussel Industry Council (NZMIC) in response to a bloom of the planktonic microalga *Gymnodinium catenatum*[17] off New Zealand's northwest coastline in May 2000 (MacKenzie & Beauchamp 2000).The subsequent detection of high densities of *Gymnodinium* cysts in Kaitaia spat supplies led to a voluntary industry ban on spat movements to all aquaculture regions, and the development of treatments to minimise cyst densities within infected material so that inter-regional transfers could continue (Taylor 2000). The code of practice is

[17] *Gymnodinium catenatum* produces biotoxins that result in paralytic shellfish poisoning in humans that eat infected shellfish and has been responsible for closures of shellfish aquaculture areas worldwide.

implemented as necessary based on microalgae levels (see Appendix 2 of the SMF document for green-lipped mussels).

Along with spat sourced from Kaitaia and Aotea Harbour, the Coromandel mussel industry also utilises some locally caught spat as well as spat bred in the commercial hatchery based at the Cawthron Aquaculture Park in Nelson (Pambudi & Clough 2017). Transfers of spat from the hatchery facility are expected to represent less biosecurity risk due to the spat being produced in containment with no associated biofouling organisms. Hatchery operations are required to comply with appropriate biosecurity procedures, with transfers of stock from this facility specifically required to adhere to Freshwater Fish Farm Licences administered by MPI.

In addition to spat transfers, movement of larger (~30–50 mm) ‘seed’ mussels, which are grown on longlines and then redistributed to other growing regions according to demand, also occur. A code of practice produced by NZMIC in 2001 sought to minimise the biosecurity risk associated with seed mussel transfers. The code identifies three geographic mussel farming zones[18] and requires that seed mussels moved between these zones be declumped, thoroughly washed, transferred as single seed (i.e. not attached to each other by their byssus), and visually free of several target species (see Appendix 2 of the SMF document for green-lipped mussels). While the code undoubtedly reduces the transfer of the larger macroscopic fouling species between the three zones, microscopic life-stages (e.g. spores of the kelp *Undaria pinnatifida*) and reproductively viable fragments can survive the declumping and washing process and may still be transferred (Forrest & Blakemore 2002; Forrest & Blakemore 2006).

Origin of risk: Biosecurity risks associated with the transfer of mussel spat or seed will depend on where the transfers originate from. Producing spat for use on site would negate the risks associated with spat or seed transfers. However, it is unlikely that sufficient spat could be reliably obtained on site to service any new farm developments. Similarly for the existing farms, spat is likely to be sourced from Ninety Mile Beach, in the Northland region or from Aotea Harbour. At present, there is only one high-profile pest species present in Northland that is not currently recorded from the Waikato CMA (the solitary sea squirt *Pyura doppelgangera*). It is conceivable that propagules or juveniles of this species could be transferred with mussel spat or seed transfers, although as it is a predominantly hard-bottom fouling species that colonises rocky coastlines, this is less likely. There are no known pest species of concern in Aotea Harbour.

[18] The three zones are: northern New Zealand (north of Mahia Peninsula including the Firth of Thames and Coromandel); southern New Zealand (south of Kaikoura); and a central zone between these two (which includes the Marlborough Sounds and Golden/Tasman bays).

Novelty of risk: Movement of mussel spat or seed into the Waikato CMA represents an existing biosecurity risk to the region and does not involve new vector pathways into the Waikato CMA.

Magnitude of risk: Even though there are extensive mussel farming operations in the region currently, the transfer of mussel spat or seed from other growing regions into the Waikato CMA still represents an important risk in terms of HMO introduction. The mussel industry has processes in place for spat and seed transfers that assist in reducing associated biofouling. However, these mechanisms are largely based around risk reduction rather than prevention, with several known instances where marine pests have been transferred between and within regions through movements of shellfish stock (e.g. *Didemnum vexillum* in the Marlborough Sounds).

Mitigation options

Mitigation options for biosecurity risks associated with the movement of mussel stock could include:

1. Require all spat/seed stock to be sourced on site, locally or from hatcheries.

To the extent feasible, spat obtained on site or locally (i.e. from within the same growing region) should be used to stock the farm. Producing spat for use on site would negate the risks associated with spat or seed transfers. Similarly, sourcing spat or seed stock locally would prevent the introduction of HMOs not already found within the Waikato region. A further option could be to require spat to be sourced from a certified hatchery facility, as this is produced in a contained environment and largely free of biofouling organisms.

The feasibility of sourcing stock on site is entirely dependent on the farm being located in a 'spat-catching' area. It is unlikely that sufficient spat will be sourced on site to service the entire farm. In the same manner, a requirement for sourcing stock locally would also be restricted by mussel population dynamics of the region.

2. If local spat/seed is not available, any transfer of stock from other regions should adhere to the SMF protocol for stock movements.

In the event that spat or seed is brought to the farm from other growing regions (e.g. outside the Waikato region), a small incremental risk exists. Where spat or seed needs to be sourced from other regions, the SMF document provides guidance for transfer, based on the following measures:

- declump (where feasible), wash, and inspect spat and seed being brought onto the farm from other regions, so that it is free of visible biofouling and sediment
- dispose of excess or damaged spat and seed at an appropriate landfill

- keep records of all spat and seed transfers, including transfer date, origin/destination, the amount or volume moved, duration out of water, and whether declumping and/or washing (or other treatment) was undertaken
- report any suspected new or notifiable pests or diseases (or signs of disease) to the MPI Exotic Pest and Disease Hotline (0800 80 99 66).

The precautions outlined above are based around risk reduction rather than prevention. They represent feasible measures that can be implemented by the industry. Although a range of more 'biosecure' treatment measures (e.g. hot water, acetic acid, bleach) have been investigated for mussel stock transfers in New Zealand (see Forrest & Fletcher 2015), none have been developed as routine operational practices for reasons relating to cost and practicality. That being so, treatment measures could be required to address specific risks (e.g. known outbreak of a pest species in a source region).

As with equipment and gear movements, there should be a requirement for recording and reporting on stock transfers intra-regionally (i.e. among the main aquaculture areas within the Waikato region) as well as movements into the Waikato CMA.

3. Requirement for no transfer of stock with known (or suspected) diseases or parasites, or sourced from locations experiencing mortalities.

There should be no transfer of stock with known (or suspected) diseases or parasites, or that is sourced from locations experiencing mortalities. Operators should be required to maintain records that provide evidence for disease- and parasite-free status of transferred stocks and source areas. Ideally such information would be recorded consistently and, for the Waikato region, be collated by WRC.

6.2.4. Farm-scale biosecurity risks

A mussel farm development will result in increased amounts of submerged backbone lines with associated floats, anchors, and dropper lines. This, along with the cultured mussels themselves, is a significant structure with the potential to alter the local environment within or adjacent to the farm. In the case of an introduced species that is new to the region, the mussel farm could act as a population reservoir that infects the wider environment. Likewise, the increase in biomass of farmed stock could favour the emergence and possible proliferation of a disease.

Origin of risk: Farm-scale biosecurity risks will largely be restricted to the nearby area. In the event of a new HMO to the region, the farm could be colonised and subsequently act as a 'stepping stone' for further dispersal of the species.

Novelty of risk: The novelty of biosecurity risks associated with the creation of space through mussel farm developments will depend on the farm location, and more specifically, the number of existing artificial structures in the nearby vicinity. It is important to recognise that the potential for aquaculture to contribute to the establishment of HMOs in the wider environment is in many instances an incremental risk to that which already occurs.

Magnitude of risk: The importance of additional habitat created from mussel farming operations in relation to other artificial structures nearby will be situation-specific. At the scale of an individual mussel farm, the incremental reservoir risk may be relatively unimportant. The magnitude of risk will largely depend on the scale of development, the extent of the increase of submerged structures and their importance relative to existing structures in the region.

Mitigation options

Mitigation options for farm-scale biosecurity risks related to mussel farming are the same as those proposed for finfish farming (see Section 6.1.4).

1. Require 'passive' surveillance within the farm to enable early detection of HMOs.
2. Require control of HMO populations where feasible.
3. Require development of measures to control disease outbreaks.
4. Require cleaning of farm infrastructure to occur on site, or if in a land-based facility, requirement for debris to be disposed of at an appropriate landfill.

6.3. Oyster farming

At present, there are 16 consented oyster farms located within the Waikato CMA, including within harbours on both the east and west coast of the Coromandel Peninsula and within Kawhia Harbour on the west coast on the region. These farms occupy ~70 ha of water space and produce ~500 tonnes of Pacific oysters per year (Pambudi & Clough 2017). There is presently no farming of flat oysters (*Ostrea chilensis*) in the Waikato CMA. Pacific oyster culture mainly involves cultivation on elevated intertidal racks made from treated timber. Racks are arranged in parallel rows that allow vessel access between them and are only visible at low tidal states (e.g. neap tide level or lower). An alternative cultivation method recently trialled in Marlborough involves culture of Pacific oysters using conventional floating subtidal lines similar to green-lipped mussels, with the oysters grown in baskets or trays (Forrest & Hopkins 2017).

The Pacific oyster industry has had issues with HMOs in the past, historically relating to mudworm and flatworm infestations (Handley & Bergquist 1997), associations with fouling pests such as the sea squirts *Styela clava* and *Eudistoma elongatum* (Coutts & Forrest 2005; Smith *et al.* 2007), and more recently the emergence of the ostreid herpes virus (OsHV-1) in 2010. This virus has been associated with significant mortalities of cultured oysters and spat and has significantly impacted the industry

(Castinel & Atalah 2015; Castinel *et al.* 2015). Since the ostreid herpes virus outbreak there has been increased focus on biosecurity issues and associated management options (Castinel *et al.* 2014). Several previous reports have also addressed the broader ecological effects associated with Pacific oyster culture (see Forrest *et al.* 2009b; Keeley *et al.* 2009). We provide a high-level summary of the information contained in these documents, with readers directed to the source literature for a more comprehensive assessment.

The sources of biosecurity risk from oyster aquaculture are similar to that for mussel aquaculture and relate to the potential for domestic spread of pest species by farming activities. As with finfish and mussel farming, four broad sources of marine biosecurity risk that may arise as a result of oyster farming activities have been identified:

1. Risks associated with culture-related vessel movements; of particular importance is the origin of any vessels arriving from outside the Waikato CMA.
2. Risks associated with the transfer of culture-related equipment and gear (e.g. oyster sticks and frames) between farm sites.
3. Risks associated with movement of stock, in particular the movement of oyster spat from collection areas to grow-out sites.
4. Farm-scale risks associated with site itself, including the farm providing a reservoir for the spread of HMOs to the environment or the farm creating environmental conditions that enhance established HMO populations.

An overview of each risk type, as well as potential options for mitigation of associated risks, is provided below. Aquaculture New Zealand's 'Sustainable Management Framework' (SMF) document for Pacific oysters provides up-to-date objectives and guidelines for minimising biosecurity risks common to oyster farming in New Zealand[19]. The guidelines represent industry best practice and, when implemented, should reduce risk to a level that is acceptable in light of current activities. As such, specific mitigation options proposed below are largely based on the best practice Operational Procedures described in Appendix 2 of the SMF.

6.3.1. Vessel movements

As with mussel farming, vessel movements associated with oyster farming operations may occur in relation to farm construction, farm servicing, and harvesting of stock. Vessel types are largely restricted to barges and launches (including trailered craft). Risk mechanisms are the same for vessel movements in general (see Section 2.3.1), aside from ballast water risks which are not directly relevant to mussel aquaculture in New Zealand given the comparatively small size of the vessels in this industry. Due to nature of oyster farming operations, the biosecurity risk from entrained sediments is perhaps higher for oyster farming, when compared to other aquaculture sectors.

[19] http://www.aplusaquaculture.nz/#frameworks

Origin of risk: Vessel movements associated with day-to-day operations are expected to be geographically limited, with most farm-related vessels not moving outside of the Waikato CMA. Vessels visiting for one-off events such as infrastructure maintenance will pose a risk if they have travelled from outside the region. The level of risk will be dependent upon where the vessel has originated from, and whether the region of origin has established HMOs populations not currently present within the Waikato region or part of the region therein.

Novelty of risk: Risks posed by vessels used during day-to-day operation of the oyster farm will be common to the already existing aquaculture operations (i.e. oyster and mussel farming) within the Waikato region. Therefore, their activity is not likely to lead to novel biosecurity risks. Any non-industry vessels visiting the farm for specific tasks are likely to represent an additional biosecurity risk; however, in particular those which arrive from other regions or internationally.

Magnitude of risk: As discussed for finfish and mussel farming, existing sources of biosecurity risk include international vessel arrivals into the Hauraki Gulf, and domestic vessel movements into the Waikato region or the immediate vicinity (e.g. recreational vessels, fishing boats, tourism operators, barges, merchant ships). Farm-related vessel movements are therefore expected to represent a relatively minor risk to the region.

Mitigation options

Mitigation options for the movement of oyster farming-related vessels are the same as those proposed for finfish farming (see Section 6.1.1).

1. Require all vessel operators to adhere to good maintenance standards.
2. Require notification of any vessel movements from outside the Waikato CMA.
3. Restrict the movement of farm-associated vessels into the Waikato CMA from regions of high-risk.

6.3.2. Equipment and gear movements

Previously-used equipment such as grow-out sticks, bins, bags and footwear may be transferred between oyster growing regions occasionally. A range of HMOs could be transferred with these items, including biofouling species and those associated with sediments.

Origin of risk: The biosecurity risks posed by equipment associated with oyster farms are dependent on whether or not transfers between farms occur, and where the transfers originate from. Transfers between farms in the same farming region (i.e. within the Coromandel) are expected to pose fewer biosecurity risks; however, there is the potential for the development of new populations within a region through this transport mechanism. Transfers from other regions (particularly those with established

HMOs populations not currently present within the Waikato CMA) will represent a high risk to the recipient region.

Novelty of risk: As most transfers of equipment and gear between oyster farms are expected to be within the same growing region, they are not likely to lead to novel biosecurity risks to the Waikato CMA. That being so, the transfer of equipment or gear into the Waikato CMA from another region introduces novel biosecurity risks and will need to be managed appropriately.

Magnitude of risk: The transfer of oyster farm equipment and gear within the Waikato CMA is not likely to pose an unacceptably high level of risk. Appropriate and effective treatments are expected to mitigate this risk to a high degree.

Mitigation options

Mitigation options for the movement of oyster farming-related equipment and gear are the same as those proposed for mussel farming (see Section 6.2.2).

1. Require the use of new equipment or gear for development of new farms.
2. Require all previously-used equipment or gear to be thoroughly cleaned and treated appropriately.
3. Require adequate record-keeping of any equipment and gear movements.

6.3.3. Stock transfers

Spat for oyster farm stocking can be sourced locally by catching spat at the farm itself, or it can be transferred to the farm through purchase of either single seed nursery oysters, stick-caught small oysters, or catching/picking of wild spat from outside the farm under a commercial fishing permit. Spat and seed oysters are often transferred between regions which may result in the inadvertent transfer of associated organisms. This may include biofouling organisms on the shellfish itself or those inhabiting associated muddy sediments. To our knowledge, no wild-caught Pacific oyster spat are produced locally, with the majority coming from Kaipara Harbour on the north western coast of the North Island. Spat are transferred on wooden sticks all year round. On occasions, large oysters have previously been transferred between growing regions for flushing (depuration) when water quality in the home harbour has fallen below standards acceptable for shellfish rearing (Taylor *et al.* 2005).

Origin of risk: Biosecurity risks associated with the transfer of spat or seed oysters will depend on where the transfers originate from. With reference to spat oysters being transferred from the Kaipara Harbour, at this point in time, the only high-profile HMO known to be established in that region but not in the Waikato CMA is the Japanese mantis shrimp (*Oratosquilla oratoria*).

Novelty of risk: Movement of spat or seed oysters into the Waikato CMA represents an existing biosecurity risk to the region and, unless farmers begin sourcing stock from a new farming area, does not involve new vector pathways into the Waikato CMA. New farm developments would result in an incremental increase in risk to the existing situation.

Magnitude of risk: Transfer of hatchery-produced oysters is likely to pose a relatively low biosecurity risk, as hatchery spat are unlikely to have been associated with risk species. However, the transfer of spat or seed oysters from other growing regions into the Waikato CMA represents an important biosecurity risk. Without management intervention (e.g. treatment measures to reduce the risk of transferring pest species) the risk of transporting HMOs during stock movements can be high.

Mitigation options

Mitigation options for biosecurity risks associated with the movement of oyster stock could include:

1. Require all spat/seed stock to be sourced on site, locally or from hatcheries.

To the extent feasible, spat obtained on site or locally (i.e. from within the same growing region) should be used to stock the farm. Producing spat for use on site would negate the risks associated with spat or seed transfers. Similarly, sourcing spat or seed stock locally would prevent the introduction of HMOs not already found within the Waikato region. A further option could be to require spat to be sourced from a certified hatchery facility, as this is produced in a contained environment and largely free of biofouling organisms.

The feasibility of sourcing stock on site is entirely dependent on the farm being located in a 'spat-catching' area. It is unlikely that sufficient spat will be sourced on site to service the entire farm. In the same manner, a requirement for sourcing stock locally would also be restricted by oyster population dynamics of the region.

2. If local spat/seed is not available, any transfer of stock from other regions should adhere to the SMF protocol for stock movements.

In the event that spat or seed is brought to the farm from other growing regions, a small incremental risk exists. Where spat or seed needs to be sourced from other regions, the SMF document provides guidance for transfer, based on the following measures:

- spat and seed being brought onto the farm from other regions should be washed prior to movement, so that it is free of visible biofouling and sediment
- dispose of excess or damaged spat and seed at an appropriate landfill

- keep records of all spat and seed transfers, including transfer date, origin/destination, the amount or volume moved, duration out of water, and whether washing (or other treatment) was undertaken
- report any suspected new or notifiable pests or diseases (or signs of disease) to the MPI Exotic Pest and Disease Hotline (0800 80 99 66).

The precautions outlined above are based around risk reduction rather than prevention. They represent feasible measures that can be implemented by the industry. As with equipment and gear movements, there should be a requirement for recording and reporting on stock transfers intra-regionally (i.e. among the main growing areas within the Waikato region) as well as movements into the Waikato CMA.

3. Requirement for no transfer of stock with known (or suspected) diseases or parasites, or sourced from locations experiencing mortalities.

As with finfish and mussels, there should be no transfer of stock with known (or suspected) diseases or parasites, or that is sourced from locations experiencing mortalities. Operators should be required to maintain records that provide evidence for disease- and parasite-free status of transferred stocks and source areas. Ideally such information would be recorded consistently and, for the Waikato region, be collated by WRC.

6.3.4. Farm-scale biosecurity risks

Most farmed Pacific oysters are cultivated on intertidal racks, structures which are vulnerable to colonisation by risk species that favour such habitats. Any new farm developments will provide additional areas of artificial habitat and will potentially facilitate the expansion of native organisms to new areas and potentially aid the invasion of exotic species. Once pest species become well-established on such structures, the resulting reservoir of propagules has the potential to further facilitate spread to adjacent habitats. It should be noted that in the case of elevated intertidal culture the tidal height at which the crop is grown can prevent or reduce infection by many of the notorious pests described for subtidal floating systems (Ramsay *et al.* 2008). For example, the clubbed tunicate *Styela clava* can reach high densities on intertidal rack structures, but is often uncommon at the top of the racks where crop grow-out occurs (Forrest *et al.* 2009b).

Oyster farms can also facilitate the spread or establishment of certain HMOs through alteration of seabed habitats as a result of shell deposition, or through a change in sediment physico-chemical characteristics because of biodeposition (faeces and pseudo-faeces) from the cultivated stock (see Taylor *et al.* 2005). Previous research has described elevated densities of the non-indigenous bivalve *Theora lubrica* in enriched or otherwise disturbed sediments in the vicinity of oyster farms in Mahurangi

Harbour (Forrest & Creese 2006). The wider range of environmental effects of oyster farming are reviewed in Forrest *et al.* (2009b).

Origin of risk: Farm-scale biosecurity risks will largely be restricted to the nearby area. In the event of a new HMO to the region, the farm could be colonised and subsequently act as a 'stepping stone' for further dispersal of the species.

Novelty of risk: The novelty of biosecurity risks associated with the creation of space through oyster farm developments will depend on the specific farm location, and more specifically, the number of existing artificial structures in the nearby vicinity. As discussed for finfish and mussel farming, it is important to recognise that the potential for aquaculture to contribute to the establishment of HMOs in the wider environment is in many instances an incremental risk to that which already occurs.

Magnitude of risk: The importance of additional habitat created from oyster farming operations in relation to the rocky shores, reefs and other farms nearby is uncertain. At the scale of an individual mussel farm, the incremental reservoir risk may be relatively unimportant. The magnitude of risk will largely depend on the scale of development, the extent of the increase of submerged structures and their importance relative to existing structures in the region.

Mitigation options

Mitigation options for farm-scale biosecurity risks related to oyster farming are the same as those proposed for finfish farming (see Section 6.1.4).

1. Require 'passive' surveillance within the farm to enable early detection of HMOs.
2. Require control of HMO populations where feasible.
3. Require development of measures to control disease outbreaks.
4. Require cleaning of farm infrastructure to occur on site, or if in a land-based facility, requirement for debris to be disposed of at an appropriate landfill.

6.4. Other potential farmed species

At present, the only aquaculture activities occurring in the Waikato CMA are mussel and oyster farming. Aside from finfish developments, which have been covered earlier in this report (see Section 6.1), there are a number of additional species which could be considered for farming in the future (see MPI 2013). Species have been grouped depending on whether there are current farming operations in New Zealand (flat oysters and pāua), whether the candidate species are deemed to have short-term potential for aquaculture (i.e. < 5 years to commercialisation; sea cucumbers, Asian kelp, geoducks) or long-term potential (i.e. > 5 years to commercialisation; scallops, toheroa, other macroalgae, sponges).

Biosecurity implications will be species-specific, with the highest risk associated with industries that: have a high degree of transfer between regions; involve species not naturally widespread or indigenous to the bay or region to be farmed; and do not have biosecurity protocols for stock or equipment transfer and management in place (see Keeley *et al.* 2009). That being so, the four main sources of marine biosecurity risk that may arise from farming of any emerging species are likely to be consistent with the current aquaculture sectors:

1. Risks associated with culture-related vessel movements; of particular importance is the origin of any vessels arriving from outside the Waikato CMA.
2. Risks associated with the transfer of culture-related equipment and gear between farm sites.
3. Risks associated with movement of stock, in particular the movement of juveniles from collection areas to grow-out sites.
4. Farm-scale risks associated with site itself, including the farm providing a reservoir for the spread of HMO's to the environment or the farm creating environmental conditions that enhance established HMO populations.

As any new farming activities will be situation-specific, it is outside the scope of the current report to assess the biosecurity risks associated with potential species in entirety. Instead, an overview of the species (or group of species), likely farming methods and any known biosecurity-related issues is provided below (largely sourced from Forrest & Hopkins 2017).

6.4.1. Other species currently farmed in New Zealand

Flat oysters

Flat oysters (*Ostrea chilensis*) have previously been commercially grown at a small scale in both the Marlborough Sounds and Stewart Island, with some additional holding of wild dredge oysters for fattening. Farming methods use floating subtidal lines the same as for the mussel industry, with oysters grown in trays or lantern cages, or suspended from ropes. The industry has been heavily affected by the exotic parasite *Bonamia ostreae*, which resulted in the removal of all stock from the Marlborough and Stewart Island farms in August 2017.

Pāua (abalone)

Pāua (*Haliotis iris*) aquaculture in New Zealand is mostly conducted in land-based systems, which can accommodate all phases of production (spawning, larval rearing, seed production and grow-out). Many hatcheries also now produce juveniles for reseeding and replenishment of wild stocks (Keeley *et al.* 2006). At present there are two small sea-based operations (in Banks Peninsula and Stewart Island), producing small amounts of pāua, either for pearl cultivation or grow-out for harvest. Pāua are typically farmed in barrels suspended from conventional floating subtidal lines and are fed on macroalgae (e.g. *Macrocystis pyrifera*, *Lessonia* sp., Durvilliae and *Pterocladia* spp.) or specially designed feed pellets. Worldwide abalone species are susceptible to a number of disorders, diseases, viruses and parasites, none of which are presently problematic in New Zealand pāua. There are reports of a farm-originated virus spreading to wild abalone populations in Tasmania, resulting in significant mortalities (Hine 2006).

6.4.2. Species with short-term potential

Sea cucumbers

Sea cucumber are not currently farmed commercially in New Zealand, but some experimental trials have been undertaken. The most likely candidate species is *Australostichopus mollis*. Sea cucumbers are deposit-feeders, obtaining their nutritional requirements from processing large volumes of sediments on the seafloor, digesting the organic components (algae, diatoms, cyanobacteria) and excreting unwanted sediments (Uthicke 1999). If farmed commercially, they are likely to be grown on the seabed possibly using bottom-oriented cages (Slater & Carton 2007). There is a possibility of feed-added culture methods being used. Being deposit feeders, sea cucumbers may be grown in co-culture situations (e.g. with bivalve and finfish farms) due to their potential to mitigate organic enrichment (Slater & Carton 2007; Keeley *et al.* 2009). Disease issues have been reported for sea cucumber aquaculture overseas (MPI 2013).

Asian kelp, *Undaria pinnatifida*

Undaria is cultivated overseas, mainly for human consumption as 'Wakame'. There has been previous research on the aquaculture potential of *Undaria* (Hay & Gibbs 1996; Gibbs *et al.* 1998; Gibbs *et al.* 2000). However, its legal status as an unwanted organism under the Biosecurity Act means any aquaculture developments will require situation-specific consideration that set it apart from native algal species. MPI has identified a few locations where *Undaria* is well established and where permits for aquaculture can be applied for (at present this only includes areas in Wellington, Marlborough, and Banks Peninsula). The likely method of culture would be floating subtidal lines. There is potential for bioremediation through culturing of *Undaria* in integrated systems due to the ability of macroalgae species to mop up excess nutrients (e.g. those discharged from fish farms) (see Keeley *et al.* 2009).

Geoduck

Geoduck (*Panopea zelandica* and *Panopea smithae*) are bivalves which have exceptionally high economic value. Culture in New Zealand is currently only at the field-trial stage. Both on-ground (in PVC pipes embedded into the substratum) and elevated (near-seabed) methods are being tested. On-ground culture would likely be shallow subtidal (i.e. at wadeable depths) and may require predator exclusion cages or nets (Heasman *et al.* 2016). Elevated methods may involve use of subtidal culture trays or bins supported/suspended just off the seabed. Depths may range from very shallow subtidal to c. 20 m (Forrest & Hopkins 2017). No disease issues have been reported for geoducks in the wild in New Zealand (Heath 2014)

6.4.3. Species with long-term potential

Scallops and toheroa

Scallops (*Pecten novaezelandiae*) and toheroa (*Paphies ventricosa*) are both regarded as having aquaculture potential, although commercialisation is not expected in the short term. In the wild, scallops tend to be less aggregated and more widely dispersed than mussels and exist partially immersed in soft sediments (Keeley *et al.* 2009). Over the last 20-30 years repeated attempts have been made to culture the species in suspension, but this habitat requirement has been difficult to replicate or overcome and as such, commercially feasible culture methods do not presently exist. Experience from wild populations indicates that while numerous parasites are found in New Zealand scallops, none appear to present a serious threat and only a few have pathological significance. Toheroa are more likely to be grown using elevated subtidal culture methods as described for geoduck above.

Other macroalgae

Aside from *Undaria*, the potential for commercial culture of other macroalgae species in New Zealand has been identified. The exact species have not been identified and will depend on technological developments and demand. The likely method of culture would be floating subtidal lines and, as with *Undaria*, there is potential for bioremediation benefits from co-culture with fish farms (Keeley *et al.* 2009).

Sponges

There is interest in growing sponges for pharmaceuticals (Page 2003) or for production of bath sponges (Handley *et al.* 2003; Kelly *et al.* 2004). Commercial culture methods are yet to be established, but trials in the Marlborough Sounds involved floating subtidal line methods utilising a modified lantern net design (Kelly *et al.* 2004). Many sponges favour exposed, or high flow environments that tend to coincide with rocky coastlines and reef habitats; hence, there is potential for overlap of aquaculture requirements with high value ecological habitats. Sponges have also been considered for use in integrated culture systems as bioremediators of pathogenic bacteria (Fu *et al.* 2006).

Table 4. Summary of biosecurity risks associated with aquaculture activities. Options for risk mitigation and likely feasibility to enforce or implement is provided. Mitigation options apply to all industry sectors unless where indicated.

Biosecurity risk	**Mitigation options**	**Feasibility**
Vessel and structure movements	• Require all vessel operators to adhere to good maintenance standards	High
	• Require notification of any vessel or structure movements from outside the Waikato CMA	High
	• Restrict the movement of vessels or structures into the Waikato CMA from regions of high-risk	Low
Equipment/gear movements	• Require the use of new equipment/gear for development of the farm	High
	• Require all previously-used equipment to be thoroughly cleaned and appropriately treated (e.g. water-blasting, air-drying)	High
	• Require adequate record-keeping of any equipment and gear movements	High
Stock transfers	• Requirement for no transfer of stock with known (or suspected) diseases or parasites, or sourced from locations experiencing mortalities	High
	• Require finfish stock transfers adhere to all relevant regulatory or voluntary industry codes of practice (Finfish)	High
	• Require all spat/seed to be sourced on site, locally or from hatcheries (Mussel, Oyster)	Low
	• Require all transfers of stock from other regions to adhere to SMF protocol for stock movements (Mussel, Oyster)	High
	• Require adequate record-keeping of any stock movements	High
Farm-scale biosecurity risks	• Require 'passive' surveillance within the farm to enable early detection of HMOs	High
	• Require control of HMO populations where feasible	Medium
	• Require development of measures to control disease outbreaks	High
	• Require cleaning of farm infrastructure to occur on site, or if in a land-based facility, requirement for debris to be disposed of at an appropriate landfill	High

7. BIOSECURITY RISKS AND MITIGATION FROM ENGINEERING/MODIFICATION ACTIVITIES

Increasing population numbers leads to further development of coastal areas. This can include the construction of various structures linked to land (e.g. marinas, boat ramps, jetties, seawalls, etc.) as well as those exclusively within coastal zones (e.g. navigational aids, moorings, etc.). Often these activities will require modification of the area through activities such as dredging with associated disposal of material removed. The replacement of natural, often sedimentary, substrata with hard substrata can alter the distribution of species, particularly non-indigenous species. Due to the relative importance of shipping as a transport mechanism for HMOs, ports and marina facilities are often the sites where non-indigenous species become first established (Inglis 2001; Hayes *et al.* 2005).

WRC is responsible for large areas of coastline, with a considerable number of coastal structures located within these areas. Commercial marinas are present at Whitianga (191 berths), Whangamata (209 berths), Tairua (95 berths) and Thames (tidal facility, ~60 berths). As at June 2019, WRC has ~850 moorings recorded within their jurisdiction (pers. comm., Michael Townsend, WRC). There are also a large number of boat launching ramps within the Waikato CMA. Conditions range from unsealed launching slopes through to sealed concrete or asphalt ramps with toilets, trailer parking and boat wash-down facilities.

An overview of the biosecurity risks associated the engineering or modification-related activities that can be expected within the Waikato CMA is provided below. Discussion is focussed on generic construction and operational processes and their associated sources of biosecurity risk. Options for mitigation of particular sources of biosecurity risk are also provided. A summary of biosecurity risks associated with the development of coastal structures is given at the end of Section 7.3 (Table 5), as well as those relating to dredging and marine mining activities at the end of Section 7.4 (Table 6).

7.1. Marinas

Marinas tend to be the first port of call for international and domestic recreational vessels arriving to a new region. Along with commercial ports, they are one of the major locations (or ‘transport hubs’) for the introduction, establishment and spread of invasive species (Piola & Forrest 2009). By their nature, marinas contain an abundance of artificial surfaces, which are have been shown to be preferentially colonised by pest species (Glasby *et al.* 2007). Once established, their proliferation within or adjacent to the marina environment creates a constant source of planktonic propagules (e.g. seaweed spores or invertebrate larvae). Hence, marinas are important contributors to the biosecurity risks associated with recreational vessels.

Research has shown that marina design may exacerbate the proliferation of pest species. Many marinas are designed with solid break walls that protect vessels from high currents, winds and wave action. Water movements within enclosed marinas can create retention areas (e.g. eddies) that may entrain the propagules of pest species for longer periods of time than non-enclosed marinas. Recruitment rates of resident fouling species within enclosed marinas have been shown to be considerably greater than those in non-enclosed facilities (Floerl & Inglis 2003).

In addition, enclosed bodies of water such as those found in marinas often have significant levels of pollutants, which may favour the establishment of biocide-tolerant pest species (see Piola & Forrest 2009). Most recreational craft use copper-based antifouling coatings to inhibit the growth of fouling organisms on submerged surfaces. Despite this, studies have shown that some well recognised, non-indigenous hull fouling species, such as the bryozoan *Watersipora subtorquata*, remain able to settle and grow directly onto newly antifouled surfaces, facilitating their transport and spread (Floerl *et al.* 2004).

Several previous reports have considered the biosecurity risks associated with marina developments (Piola & Forrest 2009; Floerl *et al.* 2015; Sneddon *et al.* 2018). We provide a high-level summary of the information contained in these documents, with readers directed to the source literature for a more comprehensive assessment.

There are three broad sources of marine biosecurity risk that are associated with marina developments:

1. Risks associated with the construction phase of the marina, including from vessels, equipment or construction materials moved from elsewhere.
2. Risk associated with additional vessel movements enabled by the marina development/extension.
3. Risks associated with the structure itself, including increased artificial habitat provided by marina structures and the marina providing a reservoir for the spread of HMOs to other locations.

An overview of these risks, as well as potential options for mitigation, is provided below.

7.1.1. Construction-related activities

Many marine construction activities involve the use of specialist vessels, equipment and materials, which may be sourced from outside the region or even internationally (e.g. specialist dredges or pile-driving equipment). Risks associated with the use of vessels or equipment moved from elsewhere is largely addressed earlier under biosecurity risks associated with boating activities (see Section 5). Risk mechanisms are expected to be the same for vessel movements in general (see Section 2.3.1), aside from ballast water risks which are not expected to be relevant for vessels involved in the construction of a marina. Risk mechanisms are also largely the same for equipment and gear movements in general, including transfer through entrained sediments, entrained water and/or associated fouling or entanglement (see Section 2.3.2). The other factor to be considered is the construction materials (e.g. concrete piles) to be used for the marina development. These can be new or sourced from recycled stock which, depending on the source region, may have associated biosecurity risks.

Origin of risk: Any vessels or equipment used as part of a marina development that are entering the Waikato CMA from other regions domestically, or from outside New Zealand, may introduce biosecurity risks depending on their origin and length of time spent out of the region. Similarly, construction materials sourced from other areas may introduce HMO risks, depending on where they have come from and whether they have been appropriately treated.

Novelty of risk: Any arrivals of vessels, equipment or construction materials from outside the Waikato CMA is likely to lead to novel biosecurity risks. While representing a one-off event, these movements represent new transport pathways for HMOs into the region as opposed to an incremental increase in biosecurity risk from existing activities.

Magnitude of risk: The magnitude of risk for HMO incursions associated with the movement of vessels, equipment or construction materials is expected to be low in relation to existing biosecurity risks in the region (e.g. recreational vessel traffic, aquaculture transfers). That being so, the duration of stay of any vessel associated with the development will affect the magnitude of risk from this activity, because an increased duration roughly translates to an increased biosecurity risk. The longer a vessel or piece of equipment is deployed, the more likely it is that any associated biofouling (including microscopic life stages) will have the opportunity to grow and become reproductively mature, given suitable conditions in the recipient environment.

Mitigation options

Mitigation options for biosecurity risks related to the movement of vessels or equipment required for the marina development are the same as those proposed for large commercial vessels (see Section 5.3.1).

1. Restrict movements of vessels that do not meet certain thresholds with regards to hull antifouling and maintenance, as well as requirement to adhere to guidelines regarding gear and residual sea water.
2. Require vessels entering from outside the Waikato CMA to follow an approved Biosecurity Management Plan (BMP).

In addition, the biosecurity risks from construction materials could be addressed in the following ways:

3. Require the use of new construction materials for marina developments.

Any new marina within the Waikato CMA should be developed using new construction materials where possible. This would negate the risk of an HMO introduction. The requirement for the use of new materials is not anticipated to be overly onerous on marina developers.

4. Require all previously-used construction materials to be thoroughly cleaned and treated appropriately.

If previously-used construction materials (e.g. concrete piles) are required, they should be thoroughly cleaned, and appropriate treatments applied if necessary. The simplest treatments are washing (e.g. water-blasting) or air-drying although other options such as chemical disinfection exist. A requirement for appropriate treatment of any previously-used construction materials is likely to be largely straightforward and should not unduly interfere with the marina development.

7.1.2. Additional vessel movements

Vessel traffic is likely to increase as the result of a marina development. It could be argued that vessel traffic may increase regardless, as this reflects an increase in boat ownership in the population. If the extra marina space was not available, it may be the case that demand for new swing moorings would increase. In this respect a ‘benefit’ of a marina development is that it concentrates the incremental biosecurity risk in one area, rather than spreading it among different, and potentially new, locations in the form of scattered swing moorings (see Sneddon *et al.* 2018 for further discussion). That being so, marina developments generally result in retention of propagules and higher rates of vector infection and possible translocation of high-risk organisms.

Origin of risk: Depending on the geographical isolation of the marina development, biosecurity risk associated with increased vessel movements will be largely localised. Most of the boating activity from recreational vessels berthed at the marina is likely to be regionally confined. There will be biosecurity risks associated with vessels visiting the marina from outside of the region.

Novelty of risk: An increase in vessel activity associated with a marina development does not necessarily translate to a proportional increase in risk. A range of other pathways exist for the introduction of HMOs that are likely to be of greater regional significance.

Magnitude of risk: Recreational and commercial movements are frequent in the Waikato CMA, with the latter including aquaculture service vessels, inshore fishing vessels, and a range of passenger and tourist vessels. The incremental biosecurity risk from increased vessel traffic associated with a marina development is likely to be relatively small in the context of other risk vectors in the region. An exception could be in the case of a marina expansion, if this expansion enables vessels of different sizes or types (with potentially greater ranges) to visit then the risk profile may be modified.

Mitigation options

Mitigation options for biosecurity risks related to additional vessel movements as a result of the marina development are the same as those proposed for small recreational vessels in general (see Section 5.1.1).

1. Restrict movements of vessels that do not meet certain thresholds with regards to hull antifouling and maintenance, as well as requirement to adhere to guidelines regarding gear and residual sea water.
2. Encourage owners of permanently moored and trailered vessels to follow good maintenance practices.
3. Encourage best practice with regards to cleaning of equipment and gear.

All marinas on the eastern coast of the Coromandel Peninsula, along with those in Northland and Bay of Plenty, have now imposed a 'six or one' Marine Pest Management Programme where visiting vessels must have been antifouled in the last six months or lifted and washed in the last month[20]. Similarly, Nelson City Council has developed a requirement as part of the berth agreement for Nelson marina that boats must be free of designated marine pests or conspicuous biofouling (the latter being defined in relation to an accepted 'level of fouling' scale). These initiatives are an effective way of requiring boat operators to consider the state of their vessel hull before moving from one location to another.

7.1.3. Creation of novel artificial habitats

The installation of marina structures creates a habitat for biofouling organisms, which may include HMOs. New habitats may include a range of substrates including concrete piles, floating pontoons and the concrete breakwater panels. These structures are not antifouled and readily become heavily colonised (Glasby 1999; Glasby *et al.* 2007). Theoretically, an increase in population size of a harmful organism could lead to increased 'propagule pressure' for spread to the wider environment (Lockwood *et al.* 2005). This is of particular significance in the case of high-risk pest species which are unable to spread among marina hubs by natural mechanisms; for example, because they are limited by barriers to their dispersal or establishment (Forrest *et al.* 2009a).

[20] See: https://www.marina.co.nz/pdf/TBM-Antifoul.pdf

Origin of risk: New habitats associated with a marina development will increase the local 'reservoir' of biofouling organisms, including potentially harmful species. By acting as 'stepping stones' over potentially unsuitable areas of habitat, structures such as marinas allow species with poor dispersal mechanisms to cover greater distances. This not only allows native taxa to expand into new areas (range expansions), but also may facilitate establishment of exotic taxa that may be introduced by vessel movements (see Glasby & Connell 1999).

Novelty of risk: The appearance of relatively large areas of entirely new and uncolonised hard substrate is something which occurs naturally only rarely in coastal marine areas. Based on research conducted overseas, it appears that the assemblages that develop on artificial structures can be quite different to those in adjacent rocky areas (Connell 2001). When this is coupled with the presence of artificial vectors for the introduction of new species (in this case vessel movements), the biosecurity implications should be recognised.

Magnitude of risk: In the broader context of regional infrastructure, the increased surface area from a marina development is likely to be relatively small. Adjacent artificial habitats will exist in the form of artificial rock (rip-rap) walls, jetties, wharves, swing moorings and associated vessels, and there are also a considerable number of marine farms regionally. Collectively these artificial habitats provide an enormous surface area on which populations of marine biofouling pests can and do establish. Therefore, the new structure is likely to only represent an incremental increase in biosecurity risk from existing structures.

Mitigation options

Biofouling is not actively managed on most marine structures; the exceptions are some moorings, certain fixed structures (e.g. navigation channel markers) and marine farms. Theoretically, all marine structures could be maintained to reduce biofouling, e.g. by regular application of antifouling paint, or by regular in-water removal of biofouling biomass. This is likely to involve considerable cost, however. Several nationally or regionally-funded programmes have attempted local HMO population management on structures in New Zealand, but by and large the programmes have all have been discontinued because of considerable cost (although removal of the fanworm *Sabella spallanzanii* is currently on-going in the several marinas in the Top of the South region).

Mitigation options similar to those proposed for farm-scale biosecurity risks associated with aquaculture activities could be considered as part of new marina developments (see Section 6.1.4).

1. Require 'passive' surveillance within the marina to enable early detection of HMOs.
2. Require control of HMO populations where feasible.

WRC could also recognise where incremental spread might occur as a result of coastal development, and consider such issues as part of the planning process, e.g. by declining consent for proposed new developments that could serve as a 'stepping stone' from a major HMO reservoir to a highly-valued area (see Sinner *et al.* 2012).

7.2. Other structures linked to land above MHWS[21]

As discussed earlier, increasing population numbers have led to growing development of coastal areas, including the need for various structures within the marine zone but linked to land. This process often involves the replacement of natural habitats with artificial substrates which can alter the distribution of species, particularly non-indigenous species. Artificial substrates in the sea have been shown to be preferentially colonised by pest species (Glasby *et al.* 2007). Once established, the proliferation of pests within or adjacent to the new substrate creates a constant source of planktonic propagules (e.g. seaweed spores or invertebrate larvae). Intensive development of coastal margins can facilitate the spread of species through a 'stepping stone' process, whereby species are able to colonise adjacent structures and overcome natural barriers to their dispersal or establishment (see Forrest *et al.* 2009a).

In general, the largest risk in terms of biosecurity implications relates to structures which facilitate the arrival of vessels that would possibly not have visited the location otherwise (e.g. wharves, jetties, boat ramps). Other structures within the coastal zone, for instance culverts, causeways, groynes, stormwater outlet structures, water intake structures, seawalls, will also have associated biosecurity risks, however these primarily relate to the creation of artificial substrata.

Several previous reports have considered the biosecurity risks associated with coastal structures linked to land (e.g. Sinner *et al.* 2012; Sinner *et al.* 2013; Floerl *et al.* 2014). We provide a high-level summary of the information contained in these documents, with readers directed to the source literature for a more comprehensive assessment.

There are three broad sources of biosecurity-related risk associated with coastal structures linked to land:

1. Risks associated with construction, including from vessels, equipment or construction materials moved from elsewhere.
2. Risk associated with additional vessel movements enabled by some types of structures (e.g. wharves, jetties, boat ramps).

[21] Mean High Water Springs (MHWS) is the average throughout a year of the heights of two successive high waters during those periods of 24 hours (approximately once a fortnight) when the range of the tide is greatest.

3. Risks associated with the structure itself, including increased artificial habitat provided the structures providing a reservoir for the spread of HMOs to other locations.

An overview of these risks, as well as potential options for mitigation, is provided below. Mitigation options proposed are largely based on those outlined in another technical report (Sinner *et al.* 2012), with the reader directed to the source material for further consideration.

7.2.1. Construction-related activities

The biosecurity risks associated with the construction of coastal structures linked to land are broadly similar to those associated with the construction of a marina (see Section 7.1.1). It is unlikely that the construction of these structures would require a vessel from outside of the region; however, it could conceivably occur. In a similar manner, it is anticipated that most equipment or gear used in the construction process would be new but recycling of equipment (e.g. wharf piles) does occur on occasion.

Origin of risk: Sources of biosecurity risk will depend on the origin of any vessels or equipment used in the construction of the structure. Previously-used construction materials may introduce HMO risks, depending on where they have come from and whether they have been appropriately treated.

Novelty of risk: Construction-related activities are not likely to lead to novel biosecurity risks to the region unless specialised vessels or equipment are needed from outside the region. In that case, while representing a one-off event, these movements represent new transport pathways for HMOs into the region as opposed to an incremental increase in biosecurity risk from existing activities.

Magnitude of risk: The magnitude of risk for HMO incursions associated with the construction of coastal structures linked to land is expected to be low in relation to existing biosecurity risks in the region (e.g. recreational vessel traffic, aquaculture transfers).

Mitigation options

Mitigation options for biosecurity risks related to the movement of vessels or equipment required for the construction of coastal structures linked to land are largely consistent with those proposed for small commercial vessels (see Section 5.2.1).

1. Restrict movements of vessels that do not meet certain thresholds with regards to hull antifouling and maintenance, as well as a requirement to adhere to guidelines regarding gear and residual sea water.
2. Encourage owners of permanently moored and trailered vessels to follow good maintenance practices.

3. Encourage best practice with regards to cleaning of equipment and gear.
4. Development of industry-specific codes of practice.

In addition, the biosecurity risks from construction materials could be addressed in the following ways:

5. Require the use of new construction materials.

Any new coastal structures linked to land should be developed using new construction materials where possible. This would negate the risk of an HMO introduction. The requirement for the use of new materials is not anticipated to be overly onerous.

6. Require all previously-used construction materials to be thoroughly cleaned and treated appropriately.

If previously-used construction materials (e.g. wharf piles) are required, they should be thoroughly cleaned, and appropriate treatments applied if necessary. The simplest treatments are washing (e.g. water-blasting) or air-drying although other options such as chemical disinfection exist. A requirement for appropriate treatment of any previously-used construction materials is likely to be largely straight-forward.

7.2.2. Additional vessel movements

As with a marina development (see Section 7.1.2), vessel traffic is likely to increase as the result of the construction of some types of coastal structures. For coastal structures linked to land, biosecurity risks as a result of additional vessel movements will only be relevant for wharves, jetties and to a lesser degree, boat ramps.

Origin of risk: Biosecurity risks from increased vessel movements associated with a coastal structure such as a wharf or jetty will be largely localised, primarily resulting from vessels visiting the structure from outside of the region.

Novelty of risk: An increase in vessel movements from outside the region associated with a coastal structure such as a wharf or jetty will lead to novel risks to the Waikato CMA. However, a range of other pathways exist for the introduction of HMOs that may be of greater regional significance.

Magnitude of risk: Recreational and commercial movements are frequent in the Waikato CMA, with the latter including aquaculture service vessels, inshore fishing vessels, and a range of passenger and tourist vessels. The incremental biosecurity risk from increased vessel traffic associated with a coastal structure such as a wharf or jetty is likely to be relatively small in the context of other risk vectors.

Mitigation options

Mitigation options for biosecurity risks related to additional vessel movements as a result of coastal structures such as wharves or jetties are largely consistent with those proposed for marinas (see Section 7.1.2).

1. Restrict movements of vessels that do not meet certain thresholds with regards to hull antifouling and maintenance, as well as requirement to adhere to guidelines regarding gear and residual sea water.
2. Encourage owners of permanently moored and trailered vessels to follow good maintenance practices.
3. Encourage best practice with regards to cleaning of equipment and gear.

7.2.3. Creation of novel artificial habitats

The biosecurity risks associated with the creation of novel artificial habitats associated with coastal structures linked to land are broadly similar to those associated with marinas (see Section 7.1.3). Most structures are unlikely to have any antifouling protection applied and thus will be colonised readily. This results in an increase in population size of any resident HMOs, and thus increased 'propagule pressure' for spread to other vectors and the wider environment (Lockwood *et al.* 2005).

Origin of risk: New areas of artificial habitat associated with coastal structures will increase the local 'reservoir' of biofouling organisms, including potentially harmful species. Some structures, such as wharves, jetties or boat ramps, receive high levels of marine traffic and may represent an increased risk of colonisation by fouling organisms from outside the region.

Novelty of risk: The creation of artificial habitats from coastal structures linked to land will represent an incremental increase in biosecurity risk from existing structures. Novel biosecurity risks to the region are anticipated if the structure is isolated from other coastal structures and associated with HMO vectors (i.e. a jetty in an isolated bay), whereby it provides artificial habitats for colonisation that would not otherwise be available.

Magnitude of risk: Biosecurity risks will depend on the amount of surface area created from the construction of a coastal structure. Structures such as coastal defences add significant amounts of artificial substrate to a location. In the broader context of regional infrastructure, the risk from a storm water outlet is likely to be relatively small. The exception is where the structure acts as a 'stepping stone' for spread of HMOs, enabling species with poor dispersal mechanisms to cover greater distances over potentially unsuitable areas of habitat. Any maintenance activities related to the structures (i.e. defouling and cleaning) may also exacerbate risk. If an HMO were to be present on the structure prior to maintenance, it may inadvertently be spread via removal/fragmentation and dispersal by currents (see Piola & Forrest 2009).

Mitigation options

Mitigation options for biosecurity risks related to the creation of novel habitats through construction of coastal structures linked to land are largely consistent with those proposed for marinas (see Section 7.1.3).

1. Require 'passive' surveillance of the structure to enable early detection of HMOs.
2. Require control of HMO populations where feasible.

WRC could also recognise where incremental spread might occur as a result of coastal development, and consider such issues as part of the planning process, e.g. by declining consent for proposed new developments that could serve as a 'stepping stone' from a major HMO reservoir to a highly-valued area (see Sinner *et al.* 2012).

7.3. Structures not linked to land

There a range of structures in the coastal environment that, while directly linked to the seabed (i.e. by a mooring device), can be easily moved and transported to other locations (e.g. swing moorings, pontoons, navigation aids, wave buoys, scientific instruments, etc.). Movable structures play a role in the spread of HMOs by providing substrate for colonisation and a means to infect other associated vectors and fixed structures (Sinner et al 2013).

Swing moorings and their associated vessels have been identified as particularly high-risk with regards to HMO transfers. Factors identified as driving this risk include:

- cheaper costs associated with moorings relative to marina berths tend to result in some moorings being frequented by poorly maintained vessels
- the relative isolation of many swing moorings results in an 'out of sight out of mind' mentality to inspection and maintenance
- a lack of funding to adequately manage moorings, and a prevalence of unauthorised moorings that do not appear on any administrative records or databases.

It has been suggested that cheaper costs may attract absentee owners who are unavailable to clean and maintain their vessels, owners who use their vessels very infrequently, or users who have inherited a vessel and mooring but have little interest in boating (see Piola & Forrest 2009).

Aside from swing moorings, most other coastal structures not linked to land (i.e. navigation aids, wave buoys, scientific instruments, etc.) are typically not supposed to be used for mooring, which reduces the risk of HMO transfer. However, maintenance of some types of installations (including visual inspections and mooring-line replacement) is required by the Maritime Safety Authority of New Zealand guidelines at ‘suitable intervals’ (MSA 2004). This will require a servicing vessel to visit the structure.

As with coastal structures linked to land, there are three broad sources of biosecurity-related risk associated with those not linked to land:

1. Risks associated with installation, including from vessels, equipment or construction materials moved from elsewhere.
2. Risk associated with additional vessel movements enabled by some types of structures (e.g. swing moorings).
3. Risks associated with the structure itself, including increased artificial habitat provided the structures providing a reservoir for the spread of HMOs to other locations.

An overview of these risks, as well as potential options for mitigation, is provided below. Mitigation options proposed are largely based on those outlined in other technical reports (Piola & Forrest 2009; Sinner *et al.* 2012; Floerl *et al.* 2015), with the reader directed to the source material for further consideration.

7.3.1. Installation-related activities

While at a much smaller scale, the biosecurity risks associated with the installation of coastal structures not linked to land are broadly similar to those associated with the construction of a marina (see Section 7.1.1). It is unlikely that the installation would require a vessel from outside of the region, however, it could conceivably occur. In a similar manner, it is anticipated that most equipment or gear used in the installation process would be new, however, recycling of equipment (e.g. mooring block, chains) does occur.

Origin of risk: Sources of biosecurity risk will depend on the origin of any vessels or equipment used in the installation of the structure. Pre-used construction materials may introduce HMO risks, depending on where they have come from and whether they have been appropriately treated.

Novelty of risk: Installation-related activities are not likely to lead to novel biosecurity risks to the region unless specialised vessels or equipment are needed from outside the region. In that case, while representing a one-off event, these movements represent new transport pathways for HMOs into the region as opposed to an incremental increase in biosecurity risk from existing activities.

Magnitude of risk: The magnitude of risk for HMO incursions associated with the installation of coastal structures not linked to land is expected to be low in relation to existing biosecurity risks in the region (e.g. recreational vessel traffic, aquaculture transfers).

Mitigation options

Mitigation options for biosecurity risks related to the movement of vessels or equipment required for the installation of coastal structures not linked to land are the same as those proposed for small commercial vessels (see Section 5.2.1). In addition, the biosecurity risks from construction materials could be addressed in the following ways:

1. Require the use of new construction materials.

Any new coastal structures not linked to land should be developed using new construction materials where possible. This would negate the risk of an HMO introduction. The requirement for the use of new materials is not anticipated to be overly onerous.

2. Require all previously-used construction materials to be thoroughly cleaned and treated appropriately.

If previously-used construction materials (e.g. mooring blocks, chains) are required, they should be thoroughly cleaned, and appropriate treatments applied if necessary. The simplest treatments are washing (e.g. water-blasting) or air-drying although other options such as chemical disinfection. A requirement for appropriate treatment of any previously-used construction materials is likely to be largely straightforward.

7.3.2. Additional vessel movements

Similar to a marina development (see Section 7.1.2), vessel traffic is likely to increase as the result of the installation of some types of coastal structures. For coastal structures not linked to land, biosecurity risks as a result of additional vessels movement will only be relevant for swing moorings.

Origin of risk: Biosecurity risks from increased vessel movements associated with swing moorings will be largely localised, primarily resulting from vessels visiting the structure from outside of the region.

Novelty of risk: An increase in vessel movements associated with swing moorings does not necessarily translate to a proportional increase in risk. A range of other pathways exist for the introduction of HMOs that are likely to be of greater regional significance.

Magnitude of risk: Recreational and commercial movements are frequent in the Waikato CMA, with the latter including aquaculture service vessels, inshore fishing vessels, and a range of passenger and tourist vessels. The incremental biosecurity risk from increased vessel traffic associated with swing moorings is likely to be relatively small in the context of other risk vectors.

Mitigation options

Mitigation options for biosecurity risks related to additional vessel movements as a result of swing moorings are the same as those proposed for marinas (see Section 7.1.2).

1. Restrict movements of vessels that do not meet certain thresholds with regards to hull antifouling and maintenance, as well as requirement to adhere to guidelines regarding gear and residual sea water.
2. Encourage owners of permanently moored and trailered vessels to follow good maintenance practices.
3. Encourage best practice with regards to cleaning of equipment and gear.

7.3.3. Creation of novel artificial habitats

While at a much smaller scale, the biosecurity risks associated with the creation of novel habitats associated with coastal structures not linked to land are broadly similar to those associated with marinas (see Section 7.1.3). Some of these structures are likely to be antifouled before deployment (e.g. scientific instruments), however, most are unlikely to have antifouling protection applied and thus will be colonised readily. This results in an increase in population size of any associated HMOs, and thus increased ‘propagule pressure’ for spread to other vectors and the wider environment (Lockwood *et al.* 2005).

Origin of risk: New areas of artificial habitat associated with coastal structures will increase the local ‘reservoir’ of biofouling organisms, including potentially harmful species. By acting as ‘stepping stones’ over potentially unsuitable areas of habitat, structures such as marinas allow species with poor dispersal mechanisms to cover greater distances. Vessels visiting the structures for maintenance purposes may pose a risk. In addition, some structures, such as navigational aids and channel markers, are in close proximity to high levels of marine traffic and may represent an increased risk of colonisation by fouling organisms from outside the region. Structures such as wave buoy and scientific instruments are not expected to be in the vicinity of heavy marine traffic, and the HMO pathways are likely to be limited/localised.

Novelty of risk: The creation of artificial habitats from coastal structures not linked to land will represent an incremental increase in biosecurity risk from existing structures. Novel biosecurity risks to the region are anticipated if the structure is isolated from other coastal structures and associated with HMO vectors (i.e. a swing mooring in an isolated bay), whereby it provides artificial habitats for colonisation that would not otherwise be available.

Magnitude of risk: In the broader context of regional infrastructure, the increased surface area from the installation of a coastal structure such as a navigational aid or wave buoy is likely to be relatively small. The exception is where the structure acts as a ‘stepping stone’ for spread of HMOs, enabling species with poor dispersal mechanisms to cover greater distances over potentially unsuitable areas of habitat.

Any maintenance activities related to the structures may also exacerbate risk. Maintenance of swing moorings generally involves lifting the mooring onto the deck of a barge, and scraping all growth from the ropes, chains and the mooring block. This growth is then deposited back onto the seabed at the mooring location. If an HMO were to be present on the mooring structure prior to maintenance, it may inadvertently be spread via removal/fragmentation and dispersal by currents, or via infection of the maintenance vessel itself (see Piola & Forrest 2009).

Mitigation options

Mitigation options for biosecurity risks related to the creation of novel habitats through construction of coastal structures not linked to land are the same as those proposed for marinas (see Section 7.1.3).

1. Require ‘passive’ surveillance of the structure to enable early detection of HMOs.
2. Require control of HMO populations where feasible.

Several regional councils (e.g. Marlborough District Council, Nelson City Council) now require that all swing moorings located in their jurisdictions are inspected, repaired and cleaned every two years. A similar approach could be considered for all coastal structures not linked to land that require a resource consent.

Table 5. Summary of biosecurity risks associated with the development of coastal structures. Options for risk mitigation and likely feasibility to enforce or implement is provided.

Biosecurity risk	Mitigation options	Feasibility
Movements of vessels, equipment or materials during the construction phase	• Restrict movements of vessels that do not meet certain thresholds with regards to hull antifouling and maintenance, as well as requirement to adhere to guidelines regarding gear and residual sea water, through development of a 'regional pathway management plan'	High
	• Require vessels entering from outside the Waikato CMA to follow an approved Biosecurity Management Plan (BMP)	Low
	• Require the use of new construction materials	High
	• Require all previously-used construction materials to be thoroughly cleaned and treated appropriately	High
Additional vessel movements associated with the structure	• Restrict movements of vessels that do not meet certain thresholds with regards to hull antifouling and maintenance, as well as requirement to adhere to guidelines regarding gear and residual sea water, through development of a 'regional pathway management plan'	High
	• Encourage owners of permanently moored and trailered vessels to follow good maintenance practices	High
	• Encourage best practice with regards to cleaning of equipment and gear	High
Creation of novel artificial habitats	• Require 'passive' surveillance within the marina to enable early detection of HMOs	High
	• Require control of HMO populations where feasible	Low-Medium

7.4. Dredging and marine mining

Dredging involves the removal of sediments and debris from the seabed and is often focused on maintaining or increasing the depth of navigation channels, anchorages, or berthing areas to ensure the safe passage of vessels. Several smaller cutter-suction, backhoe, clamshell and bucket dredges, hopper barges and tugs are based around the country and are used for domestic dredging and construction projects (Floerl *et al.* 2015). Capital dredging for New Zealand ports requires the extraction of much larger quantities of seabed compared to maintenance dredging, and is usually carried out by contracting larger overseas dredges (Inglis *et al.* 2013).

Marine mining includes activities that extract oil, gas or a range of minerals (e.g. iron sand, phosphate nodules) from the seafloor. In the Waikato region iron sand mining is currently the main prospect; however, there were a number of petroleum prospecting blocks within the Waikato CMA offered by New Zealand Petroleum and Minerals (NZPM) in 2017, and approximately seven exploration wells have been drilled within the Waikato CMA between 1975 and 2008 (NZPM 2018). Iron sand has been mined by dredging beach and dune sand at Taharoa, southwest of Kawhia Harbour, since 1972. The material collected is transported offshore to the Taharoa Terminal as a slurry via a 3 km pipeline (see Section 5.3). Mining of iron sand deposits has also occurred at Port Waikato's North Head since 1969, with the deposits transported 18 km overland as a slurry to the steel mill at Glenbrook. Mining of this nature requires tens of thousands of tonnes of fresh water (extracted from the Waikato River and Wainui Stream) to create the slurry.

The marine mining sector operates a range of vessel types that are used at different stages of the life-cycle of production areas (exploration, field development, field production, product transport and decommissioning), each of which can be associated with biosecurity risks (IPIECA 2010). Common vessel types include different kinds of mobile offshore drilling unit(s) (MODU[s]), barges, heavy-lift vessels, dive/ROV vessels, pipe-laying vessels, floating production storage and offloading vessels (FPSO), tankers, general supply vessels and others. Drilling rigs used for oil, gas or mineral exploration have been proven to have potential for biosecurity risk in New Zealand. In-water cleaning of an oil rig in Tasman Bay during December 2007 resulted in the deposition of small numbers of the sub-tropical brown mussel *Perna perna*, which had survived on the rig structure since its arrival from South Africa four years earlier. Extensive dredging of the defouling site was required to remove the individuals and mitigate the risk of establishment from this species (Hopkins *et al.* 2011b).

There are three broad sources of marine biosecurity risk that may arise as a result of a dredging or marine mining project:

1. Risks associated with vessel and structure movements; in particular the origin and nature of the dredge or mining vessels used to carry out the activity.

2. Risks associated with dredge spoil disposal, including transfer of HMOs and alteration and disturbance of the seabed by spoil disposal, thereby increasing the susceptibility of seabed habitats to colonisation by HMOs.
3. Risks associated with increased shipping activities enabled by a deepened channel through dredging activities.

An overview of the first two risks, as well as potential options for mitigation, is provided below. Risks associated with increased shipping activities have been covered previously under the earlier biosecurity risks associated with boating activities section (Section 5).

7.4.1. Vessel and structure movements

Vessels carrying out dredging or marine mining activities have a number of generic attributes that make them potentially high-risk as pathways for HMO transfer. The vessel involved is likely to have several risk mechanisms present, including ballast water, entrained sediments and hull biofouling (see Section 2.3.1). These types of specialised vessels also tend to have a large number of ‘niche areas’, which may pose a higher level of biosecurity risk than vessels with a more general hull design. Some niche areas do not receive antifouling treatments during dry-docking and will subsequently accumulate large amounts of biofouling growth.

In addition, vessels associated with dredging and marine mining activities are typically slow moving, travelling at speeds of 5-10 knots. Slow-moving vessels can become heavily fouled, and a slow voyage speed is generally considered to favour the survival of associated biofouling species. These vessels also typically operate for a long duration (e.g. a few months) in any one location, which leads to a greater biosecurity risk than a short-stay vessel (e.g. a merchant ship with a turn-around time of 2–3 days), assuming that the risk of organism release increases over time. More generic aspects of biosecurity risk associated with the movement of large commercial vessels are outlined in Section 5.3.

Origin of risk: Depending on the origin of the dredge vessel, the proposed activity may introduce biosecurity risks that arise from outside the region. This is particularly relevant if the dredge vessel to be used is to be brought to the region from outside New Zealand, or from a domestic location where a high-profile marine pest is established and demonstrably causes damage.

Novelty or risk: The movement of the dredge or mining vessel into the region is likely to lead to novel biosecurity risks within the activity region. These activities, while discrete, represent new transport pathways for HMOs into the region as opposed to an incremental increase in biosecurity risk from existing activities.

Magnitude of risk: It is likely that any dredging activity will be in close vicinity to domestic and international shipping routes, as well as already established populations of marine pests. Existing sources of biosecurity risk include international vessel arrivals into the region, and domestic vessel movements into the more immediate vicinity (e.g. recreational vessels, fishing boats, tourism operators, barges, merchant ships). An application to bring only a single dredge or marine mining-related vessel into the region may appear at face value to be of limited concern give the high volume of other traffic. However, there are a number of instances where similar one-off events have been implicated in the introduction of HMOs to New Zealand, examples being international movements of barges. As such, the proposed activity may represent a relatively high level of risk to the region.

Mitigation options

Mitigation options for biosecurity risks from vessel or structure movements associated with dredging or marine mining activities are the same as proposed for large commercial vessels (see Section 5.3.1).

1. Restrict movements of vessels that do not meet certain thresholds with regards to hull antifouling and maintenance, as well as a requirement to adhere to guidelines regarding gear and residual seawater.
2. Encourage vessel owners to follow good maintenance practices.
3. Encourage best practice with regards to cleaning of equipment and gear.
4. Development of industry-specific codes of practice.
5. For activities under the control of WRC, require vessels entering the Waikato CMA to follow an approved Biosecurity Management Plan (BMP).

We would recommend that any vessels associated with dredging or marine mining activities that are entering the Waikato CMA from other regions follow an approved BMP. Risk mitigation procedures for entrained sediments would be of particular importance for dredge vessels. In this case, the expected desiccation period of above-water surfaces on arrival to the region (i.e. period of air exposure since last dredging operations) should be provided.

7.4.2. Dumping of dredge spoils below MHWS

Dredge spoil disposal has been recognised as a potential vector for the translocation of HMOs from the dredge location to spoil disposal grounds (Sinner *et al.* 2012). As well as the risk from translocation, physical disturbance and alteration of the seabed as a result of spoil disposal may increase the susceptibility of seabed habitats to colonisation by HMOs. Due to habitat requirements at both locations, the highest risk of translocation and establishment arises from like-to-like transfer of sediments (i.e. mud-to-mud, sand-to-sand). Subtidal soft-sediment dwelling species are most likely to be successfully spread via this method. For example, the small bivalve, *Theora lubrica* is widespread in the Hauraki Gulf but can be particularly abundant in disturbed areas including spoil disposal grounds (Roberts 1990). Species on the MPI unwanted list that have not been recorded in New Zealand but are capable of living in subtidal soft-sediment marine habitats are the Asian clam, *Potamocorbula amurensis*, the crab, *Carcinus maenas*, and the sea star, *Asterias amurensis*. It should be noted that there are a range of other potentially high-risk species that meet these habitat requirements that have not been deemed unwanted organisms. Similarly, several high-risk species are able to colonise small areas of hard substrate within predominantly soft-sediment habitats (e.g. *Sabella* and *Styela* have been shown to establish on pieces of shell material within the Hauraki Gulf and Firth of Thames regions).

Origin of risk: The biosecurity risk associated with dredge spoil disposal will largely depend on the location of the dredging activity and whether this location has HMOs present that do not occur in the spoil disposal location. Short distance (i.e. < 1 km) translocation of HMOs by dredge spoil disposal is probably of little consequence considering the natural dispersal ability of most marine species. For spoil locations that are more widely separated, including those outside of the 12 nautical mile limit, there are a range of other considerations. The duration of planktonic larval stages of some high-risk species can range from days to months. Over that timeframe, they would be capable of dispersing considerable distances through natural dispersal mechanisms alone. Depending on local hydrodynamics, species that have established in the dredged area may have the potential for natural dispersal to the distant disposal areas.

Novelty or risk: Aside from maintenance dredging activities, which occur on a fixed schedule and generally involve the same disposal ground, the disposal of dredge spoil is likely to lead to novel biosecurity risks within the activity region. While a one-off event, the activity represents a new transport pathway for HMOs into the region as opposed to an incremental increase in biosecurity risk from existing activities.

Magnitude of risk: It is likely that any dredging activity will be in close vicinity to domestic and international shipping routes, as well as already established populations of marine pests. For disposal sites within a short distance of dredging activities, the translocation of HMOs will be of little consequence considering the natural dispersal ability of most marine species. In contrast, dredge spoil that is being transported from a high-risk site (e.g. a commercial shipping port) to a lower risk site some distance away will represent a high biosecurity risk to the recipient location.

Mitigation options

Mitigation options for biosecurity risks associated with dredge spoil disposal could include:

1. Consider HMO risk when assessing consent applications for the disposal of dredge spoil.

We recommend that the disposal ground is relatively close to the dredged area, and of similar depth and sediment characteristics. The disposal of any dredge spoil containing HMOs would then be localised, and it is arguably of little consequence for species if they are already established in the region.

Table 6. Summary of biosecurity risks associated with dredging and mining activities. Options for risk mitigation, the likely feasibility and potential reporting requirements are provided.

Biosecurity risk	Mitigation options	Feasibility
Vessel or structure movements	• Development of a Biosecurity Management Plan (BMP) specific to the vessel/structure to be used for the activity	High
Dredge spoil disposal	• Consider HMO risk when assessing consent applications for the disposal of dredge spoil	High

8. BIOSECURITY RISKS AND MITIGATION FROM VEGETATION OR HABITAT MODIFICATION

8.1. Disturbance of pest plants (intentional or incidental)

The disturbance of pest plants, whether intentional or incidental, can have several biosecurity implications. These will be most relevant if the pest plant in question can be spread by the transport of propagules or fragments. WRC have indicated that the two species of concern are salt marsh cordgrass (*Spartina* spp.) and saltwater paspalum (*Paspalum vaginatum*). An overview of the ecology of both species is provided below. A summary of biosecurity risks associated with the modification of vegetation or vegetated habitats is given at the end of the section (Table 7).

8.1.1. Salt marsh cordgrass (Spartina spp.)

Spartina was introduced into New Zealand intentionally from North America in 1913 because of its success there, and in Europe, in foreshore protection, land reclamation and marshland stabilisation (Swales *et al.* 2005). *Spartina* has subsequently spread to several regions around New Zealand where it threatens indigenous estuarine habitats. *Spartina* is the only grass genus found in the intertidal zone, where it grows in estuaries and along the margin of the tidal reaches of rivers. All *Spartina* species are perennial, clump-forming grasses growing on erect stems up to 1 m tall (Figure 5). Tall fescue, couch and some other grass species look similar to *Spartina,* but they cannot tolerate conditions found in the intertidal zone. All three species propagate readily from rhizomes (roots) and plant fragments but only *S. anglica* produces seeds in New Zealand.

Figure 5. The salt marsh cordgrass (*Spartina* spp.). Image sourced from Northland Regional Council website.

The three species of *Spartina* known so far in New Zealand have the potential to seriously damage indigenous estuarine ecosystems. *Spartina* traps sediment, raising the level of the ground above the high tide mark and modifying the intertidal zone and associated habitat. Estuaries and shallow harbours can be reduced to thin drains surrounded by weedy pasture, adversely affecting environmental values, resulting in an immense loss of biodiversity (Swales *et al.* 2005). Other effects include loss of seafood gathering sites and increased difficulty of small boat navigation.

8.1.2. Saltwater paspalum (Paspalum vaginatum)

Saltwater paspalum is a non-indigenous perennial grass that forms dense mats along the margins of tidal flats or on sandy or gravel beaches (QEII National Trust 2008). It is generally found above the intertidal zone, although the species is semi-aquatic and able to withstand frequent inundations of high-salinity water. It is most commonly found growing in a spreading mat over mud, shingle, sand or among boulders in the salt-spray zone near the high tide mark (Graeme & Kendal 2001). Paspalum's salt tolerance allows it to also grow inland where saline conditions occur. Paspalum doesn't set viable seeds and spreads only through fragmentation of plant material.

Figure 6. Saltwater paspalum (*Paspalum vaginatum*) in the upper intertidal zone. Image sourced from: http://www.smmflowers.org/bloom/pics/S44758aML.jpg

Like *Spartina*, this species changes estuarine hydrology by accumulating sediment and may reduce or exclude feeding and roosting sites for birds and alter fish spawning and feeding grounds. It is of concern having invaded the nesting areas of the endangered fairy tern (*Sterna nereis*). Paspalum is found in several areas across the upper North Island, including in several locations within the Waikato region (including the Coromandel Peninsula and Kawhia Harbour).

8.1.3. Activities leading to disturbance of pest plants

Pest plants in estuary areas can be disturbed through a range of mechanisms including human-mediated activities and natural processes. Both *Spartina* and saltwater paspalum spread through fragmentation of plant material (i.e. rhizomes or stolons). Fragmentation is often facilitated by animal grazing disturbance and natural physical disturbance such as storm surges. Excavation work associated with the development of coastal structures (e.g. marinas, pipelines, seawalls) in estuary areas containing pest plant species can lead to unintentional fragmentation (see Asher 2012). Similarly, the use of boat propellers, nets and similar can also dislodge plant material which are then spread through water currents or associated with transport vectors such as boat trailers. *Spartina* is of particular concern as it can survive long periods of time immersed in seawater.

Mitigation options

The Department of Conservation is the principal agency responsible for *Spartina* and saltwater paspalum control, which it does primarily through herbicide application. Mitigation options proposed below are for WRC staff with regards to prevention of intentional or incidental disturbance of these species as a result of activities carried out within the Waikato CMA.

1. Require consideration of pest plant disturbance in applications for resource consents.

Depending on the activity proposed and the location, WRC could require specific consideration of pest plant disturbance through the resource consent process. Conditions could be imposed whereby the development of a Weed Management Plan (WMP) is required. A WMP generally outlines details of site inspections, including pre-construction and construction-phase site visits. The specific location of pest plants is mapped in relation to the development proposed, enabling the identification of 'high risk' areas.

Specific mitigation options required through the consent conditions can be varied. A consent issued for the construction of a sewage pipeline in Nelson required the burial of 300–400 mm of soil containing plant and root stock of the introduced succulent species, *Wilsonia backhausei*, in a separate trench (Asher 2012).

2. Encourage estuary users to consider the potential for disturbance of pest plants through their activities.

An education/awareness campaign could be initiated to inform estuary users (both recreational and commercial) around the risks of pest plant disturbance. This could include information regarding how these species spread and simple measures that could be adopted by the public to prevent this occurring. For example, not dislodging plant material through use of fishing nets or boat propellers.

3. Encourage owners of trailered vessels to follow good maintenance practices.

Overland movements of trailered vessels has been identified as a biosecurity risk, particularly with regards to the spread of invasive plants (Hayden *et al.* 2009). As described earlier for small recreational vessels (see Section 5.1.1), simple measures are available to reduce biosecurity risks from trailered vessels. Trailered boats are addressed by MPI as part of their communications programme, which encourages people to undertake the following actions before moving their boat and trailer among different locations:

- Rinse down boats, trailers and all gear thoroughly with fresh water.
- Remove any debris such as weeds, crabs, and barnacles and check the anchor well (as weeds and other organisms are often brought up on the anchor and chain).
- Drain or thoroughly rinse areas where seawater might pool.
- Where possible, allow to air dry for several days before using in a new location.

Uptake of these practices could be encouraged through greater availability of wash-down facilities, and targeted education/awareness campaigns.

Table 7. Summary of biosecurity risks associated with modification of vegetation or vegetated habitats. Options for risk mitigation, the likely feasibility and potential reporting requirements are provided.

Biosecurity risk	**Mitigation options**	**Feasibility**
Disturbance of pest plants	• Require consideration of pest plant disturbance under a resource consent	High
	• Encourage estuary users to consider the potential for disturbance of pest plants through their activities	Medium
	• Encourage owners of trailered vessels to follow good maintenance practices	Medium

9. BIOSECURITY RISKS AND MITIGATION FROM DISCHARGES/POLLUTION

9.1. Marine litter and debris

Marine litter can be discarded into the sea, on the shore, or brought indirectly to the sea by rivers, sewage, storm water, waves, or winds (NOAA/UNEP 2011). Globally, the majority of marine litter originates from shipping, offshore oil and gas platforms, aquaculture installations and waterway recreational activities including diving and marinas (UNEP 2005). Of particular concern is plastic debris, which is environmentally persistent, and can spread widely and cause a range of harmful impacts within ecosystems.

Along with the impacts outlined above, the release of marine litter into the coastal environment can also have associated biosecurity implications. Significant amounts of fouling organisms have been recorded on marine litter, mostly plastic debris, in a range of locations globally (e.g. Aliani & Molcard 2003; Barnes *et al.* 2009; Gundogdu *et al.* 2017; Miralles *et al.* 2018). Common organisms documented include bryozoans, barnacles, polychaete worms, hydroids and molluscs, with all of these groups containing well-known invasive species. Litter, and the associated fouling community, can drift passively due to wind or surface currents, providing a vector for the spread of HMOs (Rech *et al.* 2016; Campbell *et al.* 2017).

A recent Waikato-based study investigated the role aquaculture and urban marine structures play in non-indigenous species transfer through the generation and accumulation of marine litter (Campbell *et al.* 2017). As part of this work, 27 beaches along the western Coromandel Peninsula were surveyed between December 2015 and January 2016. All marine litter < 50 cm in size and located within pre-defined transects was collected and preserved for later analysis of the associated fouling community. Twenty-eight types of litter were collected, with plastic rope the most common type found on the beaches surveyed. A range of biofouling taxa were present on the litter, including hydroids, bryozoans, algae and polychaetes. Two specimens of the high-profile invasive fanworm *Sabella spallanzanii* were found on two separate pieces of plastic rope. These pieces of rope were collected from the middle zone surveyed and, due to the presence of mussel byssal threads, the authors suggested they had an aquaculture origin.

Litter represents an unmanaged biosecurity threat at both regional and national scales. We recommend that litter be considered a potential vector for regional dispersal of invasive species arriving to transport hubs or areas of high urban intensification (e.g. shipping ports or marinas) and managed where possible. A summary of biosecurity risks associated with discharges/pollution is given at the end of the section (Table 8).

9.1.1. Activities leading to release of litter in the Waikato CMA

There are a range of activities occurring within the Waikato region, both controlled and uncontrolled and including marine- and terrestrial-based sources, that could lead to the release of marine litter. It has been estimated that approximately 80% of litter found on beaches and in the sea is carried there by drains, rivers and creeks—especially after heavy rains (Araújo & Costa 2007). Potential origins of riverine litter include direct dumping at riversides, discharge from boats and urban and rural run-off (Williams & Simmons 1997). Recreational users of coastal areas are also known to be a large contributor to marine litter. Recent amendments to the Resource Management (Marine Pollution) Regulations 1998 prohibit the dumping of litter in the ocean within twelve nautical miles from the shore. All litter is required to be kept on the boat and disposed of onshore. The Ministry for the Environment have been working in partnership with Maritime New Zealand to promote the changes to the regulations through the 'Don't throw it, stow it' campaign, which is largely targeted at recreational boaters.

Commercial users of coastal areas, such as the aquaculture and fishing industries, are also a well-documented source of marine litter. In particular, the change to plastic nets which don't degrade has led to increasing amounts of abandoned, lost or otherwise discarded fishing gear (ALDFG). Similarly, materials from aquaculture activities (e.g. floats, ropes, nets, buoys, etc.) are often lost during operations and can drift to other locations.

The aquaculture industry in New Zealand has a range of procedures in place to deal with marine litter from their operations. The Marine Farming Association (MFA), which represents marine farmers in the top of the South Island, have operated an Environmental Programme since the 1990s. This programme is focused on minimising the impact on the environment from debris and noise associated with marine farming activities, as well as from pollution and emissions from industry vessels and waste taken to landfill. Members participate in regular beach clean ups, including the collection of any recreational debris found. In addition, the MFA has produced a Code of Practice outlining standard operating procedures with regards to waste minimisation, including the requirement to:

- use stocking with the highest practicable percentage of biodegradable material when seeding out mussel spat
- ensure warp and backbone ropes are of a specification and condition to prevent breaking under prevailing environmental conditions
- secure all mussel farm materials to best industry practice to prevent loss to the environment
- not dispose of any non-natural material into the marine environment
- retrieve any non-natural materials (e.g. floats, ropes, anchors) no longer required from the marine environment

- wherever possible repair and reuse materials and equipment as an alternative to disposal (e.g. rope and floats)
- look for recycling options wherever possible.

There are similar guidelines available for the finfish aquaculture industry. For example, New Zealand King Salmon Company (NZKS) have produced a solid waste management plan, with the objective of minimising the risk of reductions in neighbouring amenity values caused by the accumulation of debris from marine farm operations along the shoreline and seabed (NZKS 2014). The procedures outlined aim to ensure the accidental disposal of waste to the environment surrounding the marine farm is minimised and that all solid waste is collected on the farm and disposed of appropriately. The plan also addresses routine clean-ups of solid waste (from all sources) on the foreshore by NZKS staff, and associated reporting requirements. Specific reference is given to procedures to ensure pieces of rope, twine and netting and other miscellaneous pieces of waste cannot fall into the water.

Mitigation options

Mitigation options for biosecurity risks associated with the release of marine litter could include:

1. Require minimisation of the release of litter through resource consents.

Depending on the activity applied for, WRC could require specific actions to minimise the release of litter through the resource consent process. Consent conditions relating to the loss of infrastructural materials are routinely imposed on marine farming consents. A recent resource consent issued for a mussel farm development in the Auckland region has two consent conditions specified relating to the loss of farm infrastructural materials:

> The consent holder shall remove any part of the marine farm structure, associated equipment or other debris caused by marine farming activities authorised by this consent that is washed on-shore after being lost into the marine environment, as soon as reasonably practicable after it becomes aware that such material has been found.
>
> Any non-biodegradable material lost or removed from the marine farming activities, including but not restricted to anchors, lines, timber, droppers and buoys, shall be removed from the CMA and disposed of on land.

This option will only be available for activities under the jurisdiction of WRC and will not include non-consented activities (e.g. permitted activities under the District Plan) or uncontrolled activities (e.g. recreational boating).

2. Encourage best practice with regards to marine litter management.

An education/awareness campaign could be initiated to inform users of the CMA (both recreational and commercial) about the biosecurity implications of the disposal of litter. This could include information on the persistence of non-organic material in the ocean, how these materials can facilitate the spread of HMOs and simple measures that could be adopted by the public to mitigate these risks. Users should be encouraged to follow best practice with regards to litter disposal, including publicity of Maritime New Zealand's 'Don't throw it, stow it' campaign material.

Table 8. Summary of biosecurity risks associated with discharges/pollution. Options for risk mitigation, the likely feasibility and potential reporting requirements are provided.

Biosecurity risk	Mitigation options	Feasibility
Spread of HMOs through litter	• Require consideration of the release of litter through resource consents	High
	• Encourage best practice with regards to marine litter management	Medium

10. KNOWLEDGE GAPS AND RESEARCH NEEDS

Control or eradication of HMOs is generally difficult for technical and financial reasons. Very few efforts to eradicate a marine species have ever been successful. Exceptions are instances where specific circumstances (e.g. the ability to close off an environment for treatment) have contributed to these successful management outcomes (e.g. Culver & Kuris 2000; Wotton *et al.* 2004; Hopkins *et al.* 2011b). Due to the difficulties in managing established marine pests, incursion prevention and the management of high-risk vectors is a critical aspect of marine biosecurity. Increased emphasis in this area by regulatory agencies is evident in the development of regulatory frameworks for assessing marine pest risks (e.g. Hewitt *et al.* 2009a), comprehensive border surveillance programmes, and efforts to manage risks associated with ballast water and hull fouling on international vessels arriving to New Zealand.

Simultaneously, there is increasing emphasis on the management of domestic transport pathways for marine pests, both at a regional and national level. Several regional jurisdictions in New Zealand have developed, or are in the process of developing, marine regional pathway management plans (e.g. Environment Southland, Northland Regional Council). We recommend that an analysis of the costs and benefits of developing a regional pathway management plan, similar to that outlined in Forrest and Sinner (2016) for Northland, be carried out for the Waikato CMA. We also recommend that WRC engage with other regional jurisdictions to implement better guidance around in-water cleaning of vessels, including uptake and implementation, in a way that is consistent among regions.

While acknowledging there are limitations, predictions surrounding the potential impacts of HMOs are also crucial to enabling informed management decisions and appropriate incursion response. As such, it is recognised that a better understanding of the potential ecological and economic impacts of key HMOs to values within the Waikato CMA is necessary. In particular, an increased understanding of the direct impacts of certain pests on commercial activities such as aquaculture is required. For example, the Mediterranean fanworm is now present on a number of marine farms and on the seabed in the Firth of Thames area, albeit at the time of writing in relatively low densities. However, there is currently a lack of information on how population increases of *Sabella* on farms will impact mussel production in the region, which hampers effective risk assessment for this species.

In a similar manner, there is a critical need for straight-forward and cost-effective tools to directly control biofouling pest species once established. This is particularly relevant for the New Zealand aquaculture industry which is lacking effective and affordable management tools to mitigate risks. These research needs are largely beyond WRC's remit but could be the subject of collaboratively-funded studies with other regional councils and/or MPI.

11. CONCLUDING COMMENTS

Biosecurity incursions present significant risks to a number of key commercial, social and environmental values within the Waikato CMA, including aquaculture and tourism. A wide range of activities and developments have implications for marine biosecurity within the CMA. In managing these activities, it is important that biosecurity risks are recognised and mitigated at the earliest stage possible. Human activities can introduce new invasive species to the region, increase their ranges by transporting them across barriers to their natural dispersal, and may greatly accelerate rates of spread. Management of biosecurity risk to the Waikato CMA must focus on interrupting the chain of events to prevent establishment and adverse effects.

Vessel movements are probably the vector with the greatest biosecurity risk and the most effective means of prevention is therefore to restrict the movement of, and discharge of biofouling material from, high-risk vessels and moveable structures within the CMA. The most practical means of achieving this is through development of a marine regional pathway management plan. All risk mechanisms could be addressed as part of the plan, including hull biofouling, ballast water, bilge water and entrained water and sediments associated with gear and equipment. The eastern coastlines of the Waikato region, located between Auckland which is well recognised as the most invaded marine environment in New Zealand and Tauranga which houses a substantial international shipping port, are potentially at the most risk with regards to new marine pest incursions. This area contains some significantly valuable 'assets' (i.e. sizeable aquaculture developments, areas of significant natural character). A marine regional pathway management plan would provide regulatory authorities with jurisdiction and enable more effective minimisation of biosecurity risks.

Many activities in the CMA are governed by a resource consent (e.g. dredging activities and construction of coastal facilities such as marinas and aquaculture installations). The risk from HMOs should be considered and addressed when assessing consent applications. This should include the biosecurity risk associated with both the construction and operational phases of the activity, as well as the ability of new structures in the CMA to facilitate the spread of HMOs. A requirement for all construction materials to be new, or for previously-used materials to be appropriately treated, should be considered. With reference to aquaculture activities, the movement of juvenile shellfish stock, and to a lesser extent culture-related equipment (e.g. pre-used ropes and floats), presents an ongoing biosecurity risk to the region when not managed appropriately. Adherence to industry guidelines regarding stock and equipment movements should be promoted or where possible regulated (i.e. through a requirement for farm-specific Biosecurity Management Plans for new developments).

Voluntary measures, such as a code of practice with the shipping industry to limit ballast water discharges within specific areas of high-value, should be considered.

Similarly, raising awareness among the boating community of the risk of spreading HMOs via mechanisms such as bilge water, trailered watercraft, and fouled equipment and gear (e.g. by erecting signs at marinas and boat ramps) may be useful. This could include advice to vessel operators regarding best practice options for reducing biosecurity risks associated with these mechanisms (e.g. promotion of the 'Clean Below? Good to Go' campaign for hull biofouling). Targeting behaviour-based interventions can be an effective tool. Such approaches are likely to be less costly than applying treatment measures, with simple measures such as discharging bilge water before departing from a location likely to achieve significant risk mitigation (see Sinner et al. 2013).

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