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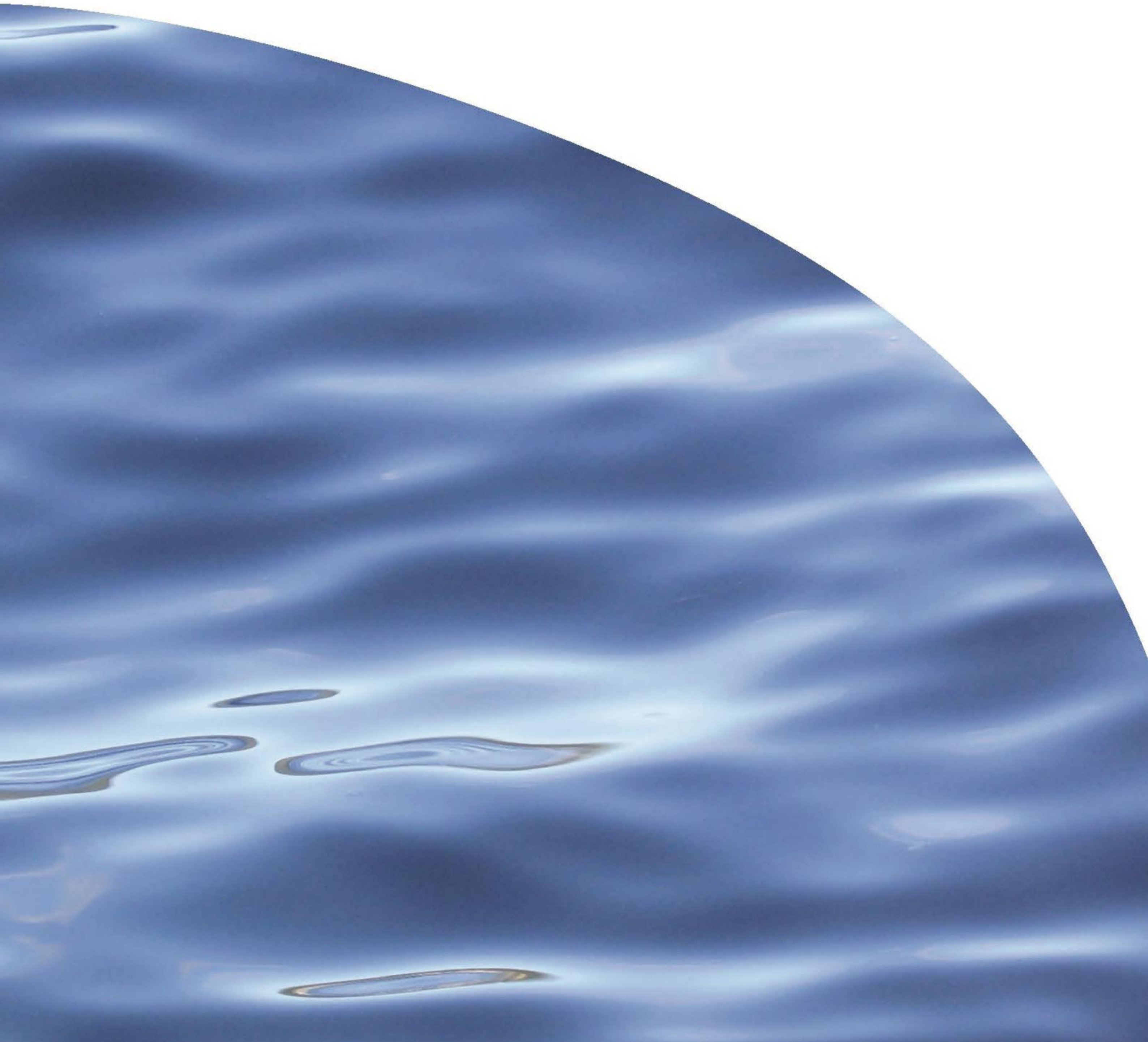
FOUNDATIONAL STRATEGIC ASSESSMENT OF BIOSECURITY RISKS FOR THE WEST COAST COASTAL MARINE AREA



FOUNDATIONAL STRATEGIC ASSESSMENT OF BIOSECURITY RISKS FOR THE WEST COAST COASTAL MARINE AREA

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EXECUTIVE SUMMARY

Scope and objectives

New Zealand's coastal environments harbour an increasing number of harmful aquatic organisms (HAOs). Vessel movements (e.g. those associated with trade, tourism, fishing, aquaculture, and research) are attributed as the most important vector for HAOs entering and moving within New Zealand. New Zealand's national and regional marine biosecurity systems have made significant steps to proactively manage biosecurity risks in recent years with new regulations and inter-agency and stakeholder partnerships to tackle this issue. The West Coast coastal marine area (CMA), administered by the West Coast Regional Council (WCRC), is relatively remote and has limited inter-regional merchant shipping; however, fishing is one of the region's primary industries. The WCRC is currently in the process of reviewing its proposed Regional Coastal Plan which will provide for HAO management guided by the New Zealand Coastal Policy Statement. Additionally, the WCRC is looking for cost-effective ways to better integrate itself into New Zealand's domestic marine biosecurity system.

To support this work, Cawthron Institute was contracted to undertake:

1. A review and synthesis of available information on biosecurity risk pathways, high-risk habitats for HAO establishment, and the potential impact of HAOs
2. An initial qualitative assessment of marine biosecurity risks and mitigation options for the region.

Key findings

Marine biosecurity risks to the West Coast CMA arise primarily from human-mediated movements into the region from areas where HAOs are established. The main ports receive infrequent and minimal merchant and international shipping. Commercial fishing vessels visit the region on a seasonal basis; other vessel types (e.g. dredges) that may harbour HAOs move in and out of the CMA as required. There is a risk that HAOs currently established in other regions of New Zealand (e.g. the unwanted organisms *Sabella spallanzanii*, *Styela clava* and *Undaria pinnatifida*) could establish within the West Coast CMA.

Our qualitative risk assessment identified a range of potential mechanisms associated with activities that may cause or exacerbate biosecurity risk and the establishment and spread of HAOs. Many of the risks identified are common to other regions, and mitigation tools are available. The risks specific to the West Coast were assigned to five categories:

1. vessel movements
2. vessel cleaning and maintenance
3. coastal infrastructure
4. dredging
5. marine farming.

For these categories, we estimated the potential consequences of effects associated with coastal activities when no biosecurity mitigation methods are in place. Limited knowledge of the present regional biosecurity status makes risks, particularly the likelihood of events, difficult to predict. The present assessment has assumed a precautionary position where, faced with issues of uncertainty, the likelihood of an effect occurring was assumed to be 'high' in all cases. The consequence of effects was apportioned into spatial scale and magnitude of effect by assessing available literature and discussing scenarios with biosecurity scientists. When no biosecurity mitigation approaches were in place, the consequences of some effects were assessed to have potentially 'large' spatial scales and 'high' magnitude. Such 'high risk' examples include the free movement of vessels, dredges, aquaculture stock and the installation of used infrastructure from other areas for coastal development and marine farming.

Given that the primary ports are river ports, with low salinity and high sediment load, there is some natural protection against the invasion of HAOs. However, there is potential for more brackish-tolerant species to establish in these areas, for example the Northern Pacific sea star *Asterias amurensis.* This species has established in south Australia, where it reaches high densities in estuarine areas and tolerates widely ranging temperatures, salinities, and substrates. There are also locations where exclusively marine species may be able to establish, for example the inshore mooring area of Jackson Bay.

Although some mechanisms of risk were identified as having potentially significant and damaging consequences, biosecurity measures to manage such risks are available and achievable. There is a range of pathway management, surveillance, and contingency planning approaches developed and available to regional councils. Many of the proactive measures are directly applicable to the West Coast region and can be supplemented by some location-specific measures.

From our review of the literature and local coastal information, recommendations to mitigate biosecurity risk to low levels are as follows:

- **Vessel movements:** work with important coastal stakeholders to promote proactive pathway management of vessels moving into and within the West Coast CMA
- **Vessel cleaning and maintenance:** availability of shore-based hull cleaning facilities that capture biofouling and cleaning waste; ensure any in-water cleaning for proactive biofouling management does not discharge biofouling into the surrounding environment
- **Coastal infrastructure:** for coastal development use new or appropriately treated infrastructure; ensure service vessels are proactively maintained and cleaned; monitor coastal infrastructure for HAOs and encourage ecological engineering for new development projects

- **Dredging:** proactively clean and maintain dredge vessels; monitor source material to be moved for the presence of HAOs, and discharge dredge spoil in suitable locations
- **Marine farming:** proactively manage aquaculture vessels, equipment and stock e.g. follow best practice vessel maintenance, equipment cleaning and treatment and monitoring of stock for HAOs or signs of HAO infection or infestation prior to movement.

In addition to these proactive biosecurity measures (i.e. preventing or minimising the risk of HAOs through pathway management), regions should aim to include environmental monitoring and surveillance to build a knowledge base that will allow for informed and adaptive biosecurity management into the future. Contingency planning for instances of HAO incursion is also important to ensure rapid response is achievable and timely.

Implementing the above recommendations can be done in numerous ways including the incorporation of marine biosecurity considerations into resource consents (e.g. controls around aquaculture movements, and coastal development and dredging), regulating vessel cleaning to prevent discharges, considering the development of pest, pathway and small-scale management plans (as needed) through the Biosecurity Act 1993, and appropriate education and awareness campaigns. We recommend implementing a marine biosecurity programme; however, the extent of such a programme requires careful consideration and cost-benefit analysis. In all cases, an integrative management approach should be followed seeking input and guidance from other local and national agencies, tangata whenua and relevant coastal and maritime stakeholders.

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1. INTRODUCTION

Marine biosecurity is of critical importance to New Zealand, safeguarding our maritime primary industries, coastal ecology, and social and cultural values. New Zealand was one of the first countries to have marine biosecurity enshrined in national legislation (the Biosecurity Act 1993) and to implement national and regional scale marine biosecurity initiatives (see Section 2). Although marine biosecurity is a well-established and a funded component of some regional councils, it has not yet been explored or developed for the West Coast Coastal Marine Area (CMA: Figure 1). Assessing the marine biosecurity risks and potential mitigation options for the West Coast CMA presents an opportunity to improve levels of protection against existing and future threats for the region itself, while also contributing to New Zealand's overall biosecurity system.

1.1. West Coast CMA overview

The remote and exposed West Coast CMA houses coastal biodiversity values of national significance (Neale et al. 2007; Lundquist et al. 2019). A notable feature of the West Coast CMA is the apparent absence of introduced harmful aquatic organisms (HAOs[1]). No other large marine region of New Zealand is free of introduced marine species[2], likely reflecting:

- the West Coast's position in New Zealand's coastal current systems
- comparatively few human-mediated pathways to the West Coast
- the freshwater influence in most West Coast ports.

These factors place the West Coast in a strong position to manage the risk of HAOs spreading via human-mediated pathways. The establishment of HAOs in the West Coast CMA would threaten ecological, cultural, social, and commercial values. In terms of introductions via natural water movements, the West Coast is also 'upstream' of other regions including Fiordland, Tasman and the lower North Island with the north moving West Coast current, and the south moving Tasman current (Neale et al. 2007). Regional currents could potentially facilitate natural spread of HAOs more easily than in regions of New Zealand that are less hydrodynamically interconnected.

[1] Under the New Zealand Coastal Policy Statement 2010, HAOs are defined as aquatic organisms which, if introduced into coastal water, may adversely affect the environment or biological diversity, pose a threat to human health, or interfere with the legitimate use or protection of natural and physical resources in the coastal environment.

[2] Although the West Coast CMA is considered free of marine pest species, it is also worth noting that there have not been any recent comprehensive baseline surveys to ascertain the actual status of the CMA.

1.2. Report scope

West Coast Regional Council (WCRC or the Council) is reviewing its proposed Regional Coastal Plan (Coastal Plan), and submissions were received asking for the inclusion of new policies to reduce the risk of HAO introductions. WCRC is responsible for managing a range of activities and developments in the coastal zone that may have implications for marine biosecurity. Currently the Council has no marine biosecurity policies or resources allocated to its management, and therefore the council is also considering how it can better align with other regional council marine biosecurity programmes.

Cawthron Institute (Cawthron) has been contracted by WCRC under the Ministry of Business, Innovation and Employment's Envirolink Medium Advice Grant scheme to provide an expert assessment of biosecurity risks and associated mitigation options for the West Coast CMA. This report provides a foundational assessment of marine biosecurity for the West Coast CMA, specifically:

1. review and synthesis of available information on biosecurity risk pathways, high-risk habitats for HAO establishment, and the potential impact of HAOs
2. qualitative assessment of marine biosecurity risks and mitigation options.

The term HAO is used to describe *any* species within the marine environment with the potential to cause adverse effects. As such, this 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. In line with other regional biosecurity initiatives, the focus of this report is on risks from macroscopic species only (i.e. marine pests) with acknowledgement that transport mechanisms are broadly similar between macro- and microscopic groups.

The information provided here will inform the review of the Coastal Plan as well as guide any future marine biosecurity programme. This report is a resource that WCRC staff can utilise for assessing marine biosecurity risks by linking certain activities 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 West Coast region’s coastline (blue line). The coastal marine area (CMA) extends 12 nautical miles out from the coast. Source: West Coast Regional Council.

2. OVERVIEW OF MARINE BIOSECURITY AND ITS MANAGEMENT

A range of activities through trade, tourism, coastal development, fishing, and recreation can inadvertently cause the spread of marine non-indigenous species and other HAOs via biofouling (e.g. attached to the hulls of ships and marine equipment) and in water (e.g. in ballast and bilge water). Vessel numbers are increasing, movement patterns are everchanging, and ranges are extending. This increase in vessel presence in conjunction with changing environmental conditions in marine environments that may facilitate the spread and establishment of invasive species, results in emerging and persistent threats to a range of values from introduced pests and diseases. Not all non-indigenous species are associated with negative impacts, and in a few cases native species can also cause adverse effects to the marine environment. HAOs only make up a small proportion of transferred species, but once established they can significantly degrade the marine environment that is a key part of our economic, environmental, and socio-cultural values.

In this section we provide a high-level overview of HAOs that pose biosecurity risks in New Zealand, their potential impacts, and their modes of introduction and spread that may lead to regional biosecurity risk. Many HAOs are likely to display commonalities of processes, risks and impacts. The reader is directed to additional relevant literature where it exists.

2.1. Harmful aquatic organisms and their associated impacts

At least 330 introduced species have been recorded within New Zealand’s marine environment (MPI 2015a), mostly in 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 have proliferated in their new environments and have caused, or been inferred to cause, adverse effects. These include the unwanted organisms *Undaria pinnatifida*, *Styela clava* and *Sabella spallanzanii* that are well established in many parts of New Zealand’s coast. Due to their invasive life history traits (e.g. high reproductive output and ability to compete with native species for food and space) and rates of spread, they are considered to impact coastal areas and are the focus of a number of regional marine biosecurity programmes. Predicting which species will have adverse effects is challenging and often impossible (Kulhanek et al. 2011; Forrest & Newcombe 2013). However, some common underlying traits believed to contribute to the HAO status include the organism having no major predators, the ability to modify habitat, association with human activities, genetic and phenotypic[3] plasticity, and a high degree of competitiveness (Geburzi & McCarthy 2018). Successful invaders are often species with high reproductive rates and tolerance to a wide range of environmental conditions and habitats (e.g. Troost 2010).

The introduction or spread of a HAO 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 mostly discussed with regards to the introduction of HAOs, but the specific level of impact is often challenging to quantify. Recent analyses have indicated that economic costs associated with specific pest species could be substantial (Giera et al. 2009; Soliman & Inglis 2018) and a range of other values (e.g. ecological, natural character, public health) can be adversely affected (see Sinner et al. 2012). Generalised information on the key types of HAOs is provided in Table 1, including a description of susceptible habitats and potential impacts to core values.

The West Coast CMA encompasses areas with considerable ecological and conservation value, including internationally significant estuaries, expansive tidal flats, and large areas of unmodified coastline with extensive fringing rocky reef habitats (see Lundquist et al. 2019). Introductions of HAOs into these areas may have irreversible effects, including biodiversity loss and the alteration of ecosystem function. Management of HAOs after they have established in a location is often challenging and expensive. A government-funded control programme for the Asian kelp *Undaria pinnatifida* over 1997–2004 cost ~NZ$2.8 million; however, this initiative was ultimately unsuccessful (Hunt et al. 2009; Forrest & Hopkins 2013). More than NZ$1 million has also been spent to date on a subsequent eradication attempt for *U. pinnatifida* after a single plant was discovered in Breaksea Sound, Fiordland in 2010 (Harding 2017), with further incursions in other areas of Fiordland in recent years (Cunningham et al. 2019). Considerable effort to eradicate and manage the Mediterranean fanworm *Sabella spallanzanii*, both by central government initially and continuing to date by regional councils, has occurred in response to the initial detection of this species in Lyttelton during 2008 (Read et al. 2011). Considerable amounts have also been spent on regional-scale management of the ascidians *Didemnum vexillum* and *Styela clava* due to the concerns regarding their potential impact on the aquaculture industry (Coutts & Forrest 2007; Gust et al. 2008).

[3] Phenotype refers to the observable physical properties of an organism, e.g. appearance, development and behaviour. Environmental factors can also influence phenotype.

Table 1. Generalised information on the key types of harmful aquatic organisms (HAOs), 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. Modified from Fletcher and Johnston (2019).

Type of HAO	**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. They can remove potential food sources from the water column and impact nutrient availability. They may compete for food and space with cultured species such as oysters and mussels.	*Sabella spallanzanii* *Styela clava* *Didemnum vexillum*	Submerged artificial structures (e.g. for marine farming or ports and marinas) Cultured shellfish stock Soft sediment	Ecological Economic Social/cultural Amenity
Mobile predators	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 on shellfish 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 (e.g. for marine farming or ports and marinas) 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 have been very successful at 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** *Arcuatula senhousia*	Soft sediment	Ecological Economic Social/cultural Amenity
Macroalgae species	Can form dense populations, have rapid growth rates and high reproductive output, can colonise a variety of substrata, and tolerate wide-ranging temperatures and depths. They can alter light availability and flow regime, compete with native canopy-forming species, change the presence of understory and epibiotic assemblages, and alter macrofaunal abundance and diversity.	*Undaria pinnatifida* *Sargassum horneri** *Caulerpa taxifolia**	Rocky reef Submerged artificial structures (e.g. for marine farming or ports and marinas) Cultured shellfish stock	Ecological Economic Social/cultural Amenity

Type of HAO	Description	Example species	Susceptible habitats	Potential impacts
Harmful algal blooms[1]	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. They can lead to the closure of harvest in shellfish aquaculture areas. There is ongoing nationwide surveillance to detect target harmful algal bloom 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[1]	These can cause collapses of fish and shellfish stocks having severe effects on aquaculture and commercial, cultural, and recreational fisheries.	*Bonamia* spp. Ostreid herpesvirus type 1 *Boccardia* spp. *Vibrio* spp.	Cultured shellfish stock	Public health Economic Social/cultural Ecological

[1] Information for harmful algal blooms, pathogens and parasites is included here, but risks from these groups are not specifically addressed in this report.

2.2. Recognised high-risk marine pest species

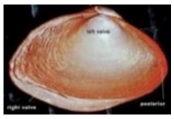
Both central and local government focus on marine HAOs that have the potential to negatively impact natural environments. Under the Biosecurity Act 1993, eight marine pest species are currently specified as 'unwanted organisms' with rules relating to their transport, sale and propagation (see Table 2). These 8 species have a history of being invasive outside of New Zealand and are also capable of establishing in New Zealand coastal waters. The Asian kelp *U. pinnatifida*, the clubbed tunicate *S. clava* and the Mediterranean fanworm *S. spallanzanii* are established in several locations throughout New Zealand. However, these species have not been reported within the West Coast CMA. The 5 remaining species are not present in New Zealand and are the focus of the Biosecurity New Zealand[4]-funded national Marine High Risk Site Surveillance (MHRSS) programme (Inglis et al. 2006; Woods et al. 2020), designed for the early detection of 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*.

In addition to those listed as unwanted organisms, two marine species are listed as 'notifiable organisms' under the Biosecurity (Notifiable Organisms) Order 2016: the red abalone *Haliotis rufescens* and the Chinese prawn *Penaeus orientalis (P. chinensis)* (Table 2). Biosecurity New Zealand also specify a further two marine pest species on their list of priority pest and diseases of biosecurity concern to plant and aquatic health[5]. These are the Asian brown mussel *Perna perna* and the Asian shore crab *Hemigrapsus sanguineus* (Table 2).

There are several other high-profile marine pest species currently present in New Zealand that have, for various reasons, not been formally designated Unwanted Organisms or Notifiable Organisms. Some of the higher profile species in this category include the Asian paddle crab *Charybdis japonica*, droplet tunicate *Eudistoma elongatum*, Asian date mussel *Arcuatula senhousia*, Australian 'cunjevoi' tunicate *Pyura doppelgangera*, vase tunicate *Ciona robusta* (formerly *Ciona intestinalis* type A), carpet tunicate *Didemnum vexillum*, and the Pacific oyster *Crassostrea gigas*.

[4] Biosecurity New Zealand is a department of the Ministry for Primary Industries (MPI)
[5] For more information, see: https://www.biosecurity.govt.nz/protection-and-response/finding-and-reporting-pests-and-diseases/priority-pests-plant-aquatic/ocean-pests/

Table 2. Marine non-indigenous species designated ‘unwanted organisms’, ‘notifiable organisms’ or priority pests and their New Zealand distribution. Modified from Piola and Forrest (2009).

Scientific and common name	New Zealand distribution	Example
Asterias amurensis [1, 2, 3] Northern Pacific sea star	Not recorded	
Carcinus maenas [1, 2, 3] European shore crab	Not recorded	
Caulerpa taxifolia [1, 2, 3] Green aquarium weed	Not recorded	
Eriocheir sinensis [1, 2, 3] Chinese mitten crab	Not recorded	
Haliotis rufescens [2] Red abalone	Not recorded	
Hemigrapsus sanguineus [3] Asian shore crab	Not recorded	
Penaeus orientalis (P. chinensis) [2] Chinese prawn	Not recorded	
Perna perna [3] Asian brown mussel	Not recorded	
Potamocorbula amurensis [1, 2] Asian clam	Not recorded	
Sabella spallanzanii [1, 2] Mediterranean fanworm	Northland, Hauraki Gulf and Firth of Thames, Tauranga, Wellington, Picton, Nelson, Golden Bay, Lyttelton	
Styela clava [1] Clubbed tunicate	Northland, Hauraki Gulf and Firth of Thames, Tauranga, Wellington, Picton, Nelson, Golden Bay, Lyttelton, Dunedin	
Undaria pinnatifida [1] Asian kelp	Widespread in harbours throughout most of New Zealand	

[1] Unwanted organism under the Biosecurity Act 1993
[2] Notifiable organism under the Biosecurity (Notifiable Organisms) Order 2016
[3] Specified on Biosecurity New Zealand’s list of priority pest and diseases of biosecurity concern to plant and aquatic health

2.3. Mechanisms for spreading harmful aquatic organisms

While natural spread is important in the establishment of self-sustaining populations of HAOs, human-mediated activities are the primary drivers of regional and national-scale spread. A number of human activities within the marine environment can intentionally or unintentionally move organisms from one place to another, with these activities often referred to as ‘pathways’ (Inglis et al. 2013). Associated with pathways are the physical means by which an organism is transported, referred to as ‘vectors’. Vectors can include vessels and moveable structures, as well as equipment or stock that is moved among different locations. Biofouling on vessels and moveable submersible structures, ballast water and material infected with pathogens or parasites are the most likely vectors for the transport of HAOs. Vessel movements (and associated equipment or infrastructure) related to maritime transport, commercial fishing, recreational boating, and aquaculture are considered the primary contributors to domestic marine biosecurity risks in New Zealand. Aquaculture is also considered a particularly high-risk activity, with potential for movement of infected stock and equipment.

A thorough understanding of all transport pathways and mechanisms of spread within a region is critical, as unmanaged vectors have the potential to compromise the overall effectiveness of other biosecurity initiatives (Sinner et al. 2013). Below we provide an overview of the main vectors and key mechanisms of transport of HAOs by these vectors.

2.3.1. Movement of vessels

The movement of vessels or structures can transport species in several different ways. Marine organisms including HAOs can be transported as part of biofouling communities on submerged surfaces (including within sea chests in ballast and bilge water) or within debris or sediments associated with equipment or gear.

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

Biofouling organisms often accumulate on vessel hulls, within internal seawater systems and within ‘niche’ areas[6] (e.g. sea chests, bow thrusters and tunnels,

[6] Niche areas are generally recessed areas on the hulls of large vessels such as the rudder, sea chests, thrusters, discharges and anodes, and are well known as harbouring substantial fouling assemblages.

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). The role of biofouling in transferring HAOs is recognised as a particularly important biosecurity risk mechanism in New Zealand (Coutts & Taylor 2004; Hewitt et al. 2009; Hopkins & Forrest 2010; Inglis et al. 2010).

Ballast water

Ballast water is the water placed in a ship to increase the draft, change the trim, or regulate stability. 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 HAOs or their dispersive life stages. If ballast water is subsequently discharged at another location, any associated HAOs may be transferred. Ballast water movements have been implicated in the spread of many HAOs, including pathogenic micro-organisms (Carlton 1985; Drake et al. 2007; Barry et al. 2008). 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 HAOs 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

Bilge water is seawater that accumulates within the hull of the vessel, including the engine room, bilge sumps and the deck of the vessel. This water enters the vessel via many ways including minor leaks, use of deck hoses and the deployment and retrieval of marine equipment like dive and fishing gear. Depending on where bilge water has originated from, it may contain a range of juvenile and adult life stages and fragments of organisms. This was highlighted by a recent survey of 30 small vessels operating within the top of the South Island region, with 118 and 45 distinct taxa detected within bilge water on board using molecular and morphological identification methods, respectively (Fletcher et al. 2017). Bilge water discharges have also been implicated in the spread of mussel species, in particular the quagga and zebra mussel, in freshwater systems in the United States (Johnson et al. 2001; McMahon 2011; Wong & Gerstenberger 2011).

Viable organisms entrained in bilge water are exposed to widely fluctuating temperatures and salinities, potentially high contaminant concentrations, and physical damage during passage through the bilge system. Because these environmental and physical factors are considered to reduce the survival of marine organisms, bilge water has received much less attention as a vector for HAOs in comparison to ballast water and biofouling. The risk from bilge water will vary with the type of vessel and bilge-pump system. However, it is likely that bilge water does present moderate risk at the domestic and short voyage scale and its risk should be evaluated in biosecurity management programmes (Fletcher et al. 2017).

2.3.2. Movement of equipment

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 HAOs within associated water or sediments and as fouling or entanglement. The risk of spreading HAOs 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 (see Fletcher & Johnston 2019).

2.3.3. Movement of livestock or 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 HAOs (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 and, to a lesser degree, sport, and recreational activities.

2.4. Biosecurity management

There is a range of international, national, and regional agreements, guidelines, policies, and legislation available to manage marine biosecurity offshore, at the border and domestically (reviewed by Sinner et al. 2013). New Zealand has engaged in active marine biosecurity management measures since the 1990s, when risk pathways such as ballast water and hull fouling gained attention and momentum via the rapid spread of established non-indigenous species (e.g. *Undaria pinnatifida*) around New Zealand’s main and offshore islands (Hay 1990; Cranfield et al. 1998; Wotton et al. 2004; South et al. 2017). Broadly, central government (Biosecurity New Zealand – Ministry for Primary Industries (MPI)) is responsible for managing the border in an attempt to keep harmful organisms out of the country, while local government (i.e. regional councils and territorial authorities) is responsible for managing those organisms once established domestically. The Biosecurity Act 1993 provides the functions and powers directly aimed at the exclusion, eradication, and management of harmful organisms.

2.4.1. Marine biosecurity at the national scale

Biosecurity offshore and at the New Zealand border is generally managed through international agreements and national legislation and is administered by Biosecurity New Zealand. The requirements around the discharge of international ballast water into New Zealand’s coastal environments are set out via an Import Health Standard issued by MPI (MPI 2016a). New Zealand is also a signatory to the International Maritime Organization’s (IMO) International Convention for the Control and

Management of Ships' Ballast Water and Sediments, which came into force in 2017 (IMO 2004 – the convention was formally adopted in 2004 and came into force in 2017) and requires ships to take action to avoid the uptake or discharge of aquatic organisms and sediments within ballast water. In 2018, the Craft Risk Management Standard for Vessel Biofouling (CRMS-BIOFOUL) was issued by MPI to manage international biofouling risks by requiring all vessels entering New Zealand to meet hull biofouling ('hygiene') thresholds and documentation requirements (MPI 2018). Biosecurity New Zealand also engage in active liaison, joint research activities and mutual knowledge exchange with their Australian counterpart—the Department of Agriculture, Water and the Environment (DAWE).

Within New Zealand, MPI Biosecurity New Zealand has operated a national-scale marine target pest surveillance programme, the Marine High Risk Site Surveillance (MHRSS) since 2001. This programme involves biannual sampling surveys around a set of national shipping ports and marinas of first entry (plus associated natural environments) and targets the HAOs set out in Section 2.2. The MHRSS programme presently excludes the West Coast CMA.

Currently, at a national level, New Zealand lacks a coordinated system for managing marine biosecurity risks posed by domestic pathways. However, the Biosecurity Act 1993 provides national and regional tools for developing such systems—including pest and pathway management plans and programmes. Active progress is being made towards more coordinated approaches, e.g. an inter-regional pathway management plan for the upper North Island. The National Policy Direction for Pest Management 2015 aims to ensure that such activities align with each other, including consistent application nationally and between regions where appropriate (MPI 2015b).

2.4.2. Marine biosecurity at the regional level

Over the past decade there has been an increase in the efforts and initiatives of regional jurisdictions to mitigate marine biosecurity risks. These activities are enabled by amendments to the Biosecurity Act 1993 that gave increased powers and obligations to regions (see Sinner et al. 2012; 2013), and partly driven by the documented establishment and spread of species such as the tunicates *Didemnum vexillum*, *Styela clava* and *Eudistoma elongatum*, the Mediterranean fanworm *Sabella spallanzanii* and the Japanese mantis shrimp *Oratosquilla oratoria*. Many regional governments now have dedicated marine biosecurity officers or even teams.

Neighbouring regions have established jointly funded partnerships, such as the Top of the South Marine Biosecurity Partnership (see http://www.marinebiosecurity.co.nz/) and the Top of the North Marine Biosecurity Partnership (see https://www.marinepests.nz/). These partnerships are good examples of integrated management involving iwi, central and local government, and maritime stakeholders. For example, the Top of the South Marine Biosecurity Partnership includes representatives and marine biosecurity practitioners from regional government (Marlborough, Nelson and Tasman), industry (Aquaculture New Zealand), science (Cawthron Institute), tangata whenua, Biosecurity New Zealand and the Department of Conservation.

Regions (e.g. Environment Southland, Northland Regional Council) have also developed their own pathway management plans, included biosecurity rules in their coastal plans (e.g. Auckland Council), or have established joint small-scale pest management programmes (e.g. a jointly funded small-scale pest management plan for *Sabella spallanzanii* in the Top of the South Island region) or recurring vessel monitoring programmes (e.g. Northland and the Top of the South) (see Forrest 2019). The Department of Conservation has also included marine biosecurity rules and risk mitigation procedures in the Regional Coastal Plan: Kermadec and Subantarctic Islands (operative September 2017). Recently, the 'six or one' rule was initiated by marinas along the North Island's eastern seaboard (Coromandel to Northland) that requires visiting vessels to have undergone hull cleaning within the last month or antifouling coating renewal within the last six months prior to entering a region or marina.

3. BIOSECURITY RISKS WITHIN THE WEST COAST CMA

A wide range of coastal activities occur within the West Coast CMA, all of which have potential risks and implications with regards to marine biosecurity. To implement appropriate management where necessary, the context and magnitude of these risks need to be understood. In the following sections we discuss the marine biosecurity implications of five specific activities that WCRC has responsibility for under the Resource Management Act 1991 and Biosecurity Act 1993 and that capture a large proportion of the overall biosecurity risk arising from anthropogenic activities in coastal marine environments. This includes an explanation of the processes, potential risks, and associated impacts involved with each activity.

3.1. Movement of vessels

Recreational yachts and launches, merchant, fishing, passenger, exploration, and research vessels, can facilitate the transport of HAOs via external biofouling, internal ballast or bilge water, or association with marine equipment (refer to the descriptions in Section 2.3). The risks to the West Coast CMA from vessel movement arise primarily from two sources:

1. introduction of HAOs via vessels arriving from other domestic locations
2. 'secondary spread' within the West Coast CMA following initial HAO establishment via (1).

3.1.1. Movement of vessels into the West Coast CMA

There are two small river ports within the West Coast CMA: Westport Harbour located in the Buller District, and the Port of Greymouth located in the Grey District. Both ports provide berthing facilities for commercial ships (cargo and fishing vessels), as well as recreational yachts and launches[7]. Because neither port is a designated Customs Port of Entry, all arrivals and departures are domestic.

Due to the isolation of the region and the exposed nature of much of the South Island's western coastline, vessel traffic is relatively limited. With no port holding a licence to be a 'Port of Arrival' for international vessels, and without having the capacity to accommodate large merchant vessels, the West Coast CMA does not receive frequent visits of larger ships servicing other domestic ports. However, both Greymouth and Westport are nevertheless part of New Zealand's domestic maritime network. The main risk is through movement of commercial and recreational fishing

[7] Personal communication with the port companies in 2016 indicated that Greymouth and Westport can provide berthing space for approximately 38 and 25 recreational yachts and launches, respectively. In comparison, Nelson, Wellington and Auckland have berthing facilities for 580, 1060 and 1600 permanently moored recreational vessels, respectively.

vessels for the hoki and tuna fishing seasons and vessel movements into Jackson Bay.

In 2016–2019, Greymouth received a total of 86 calls from fishing (80) and cargo vessels (6) that arrived from eight domestic origin ports (Bluff, Lyttelton, Nelson, New Plymouth, Picton, Timaru, Whanganui and Wellington; Cawthron unpubl. data). During the same period, Westport received calls from 85 fishing and cargo vessels arriving directly from Auckland, Bluff, Dunedin, Lyttelton, Napier, Nelson, New Plymouth, Opua, Picton, Timaru, Wellington, Whangarei and Whitianga. While the total number of vessel arrivals is relatively small (e.g. in comparison Port Nelson receives > 800 ship visits each year), connectivity with other regions is nevertheless high (see Figure 2). The environments the vessels resided in prior to their voyage into the West Coast CMA include most of New Zealand's main ports and locations of established HAOs[8].

Documented domestic arrivals appear to have been taking place for a number of years: based on an assessment of 2006 voyage data, Hayden et al. (2009) reported annual arrivals of 69 vessels into Westport and 3 into Greymouth, from the same domestic locations listed above. The data are not directly comparable to the 2016-2019 period above since the Hayden et al. (2009) study was restricted to vessels > 99 gross registered tonnes and did not capture smaller fishing vessels. However, there appears to have been a decrease in cargo vessel movements into Westport, from approximately 60 bulk carrier per annum in 2006 to 44 over the period 2016–2019. This is likely a consequence of the closure of Holcim Cement's operations out of Westport in 2016.

The arrival numbers above are derived from vessels' automatic identification system (AIS) systems which allow historic and real-time tracking. Most, but not all commercial vessels are equipped with AIS technology, however, and the actual number of domestic visits is likely higher. Personal communication with port and council representatives indicates that during the hoki and tuna fishing seasons both Westport Harbour and the Port of Greymouth attract vessels originating from all over the country. During the tuna season, the Port of Greymouth alone can berth up to 60 visiting fishing vessels at any one time. In January–March 2019, 62 domestic fishing vessels reported landing catch in Greymouth and Westport. Approximately half of these have homeports in the Nelson and Tasman regions, while the other half originated from homeports spanning the length of the country (See Appendix 1).

There are ~30 swing moorings, berthage and shelter options, along with commercial and recreational fishing facilities at the inshore area of Jackson Bay (WCRC proposed Coastal Plan 2016). There is also a rock lobster holding facility located within the

[8] Current information on marine pest distribution can be obtained from MPI Biosecurity New Zealand and The Marine Biosecurity Porthole (https://www.marinebiosecurity.org.nz/)

small township to which a small number of commercial fishing vessels land live rock lobster from fishing management area CRA 8. Depending on the market value of lobster, these vessels frequently move between Jackson Bay and the Fiordland Marine Area. The inshore mooring area receives visits from a small number of recreational and commercial vessels from outside the region depending on the time of year and weather conditions that may force vessels heading elsewhere to shelter. Fishing and recreational vessels tend to visit Jackson Bay from southern ports of Bluff and Dunedin, as well as ports and marinas in the top of the south including Nelson and Marlborough.

Little is known about domestic movements of recreational vessels into the West Coast CMA. In 2005–2007, a survey of > 1,000 domestic yacht owners returned no recorded visits (Floerl et al. 2009). Communication with the ports of Greymouth and Westport indicates annual visits of 3 to 5 recreational yachts from other domestic locations per year.

3.1.2. Movement of vessels within the West Coast CMA

AIS records from 2016–2019 (Cawthron et al. unpubl. data) indicate that a total of 777 fishing vessel voyages originated and subsequently returned to Greymouth. Over the same period, 157 fishing vessels left from and returned to Westport. Presumably, these voyages represented local vessels undertaking return trips to coastal or offshore fishing grounds during the hoki or tuna seasons or when targeting rock lobster. Resolution of AIS data is restricted to ports with designated UN LOCODEs and does not capture visits to non-port destinations such as fishing grounds. Based on a 2006 survey of > 300 commercial fishing vessels, Hayden et al. (2009) found that many of Greymouth and Westport's resident fishing vessels spend 80–110 days at sea each year, travelling as far as Fiordland, and generally use no other port facilities.

The movements into and within the West Coast CMA described in the sections above have the potential to transport HAOs in a variety of ways, including as biofouling, via internal seawater or associated with mobile equipment (e.g. fishing gear). The arrival of vessels from a wide range of domestic locations means that biosecurity risks to the region cannot be ruled out.

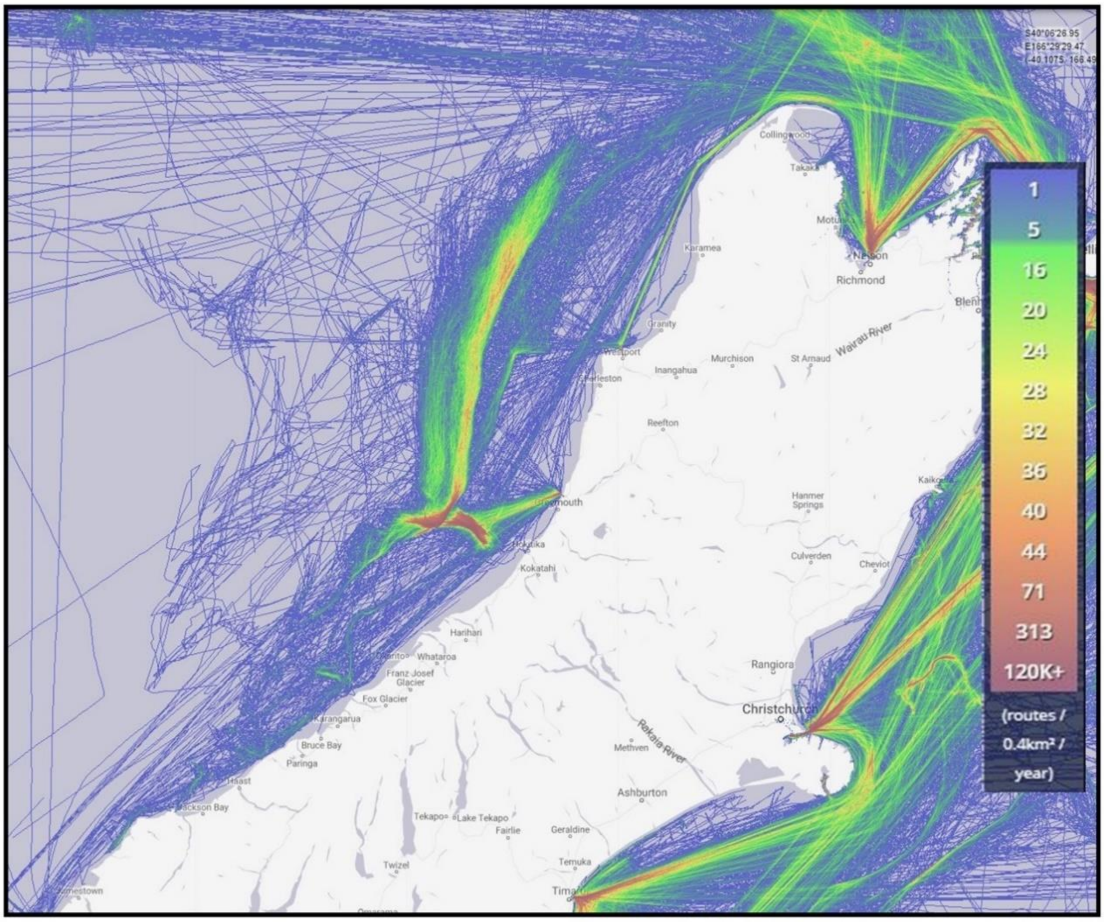


Figure 2. Vessel movements within the West Coast Coastal Marine Area (CMA) during 2017. Lines indicate density of movements (routes/0.4 km^2/year), with red colouration indicating the highest vessel traffic. Movement data are collected only for vessels fitted with an Automatic Identification System (AIS), which generally includes all cargo vessels > 500 gross tonnage, all international vessels > 300 gross tonnage, and all commercial passenger ships. Source: www.marinetraffic.com.

3.2. Vessel cleaning and maintenance

Most (if not all) ocean-going vessels have protective coatings (‘antifouling’ coatings) applied to their hull that delay the development of biofouling communities and/or corrosion of hull materials. Antifouling coatings have finite service lives of 1–5 years, depending on vessels’ operational profiles and the coating type. Once the protective performance of antifouling coatings decreases, biofouling development will start. Most vessel hulls also contain structurally complex recesses (e.g. sea chests, thrusters) or protrusions (e.g. transducers, rudder shafts, bilge keels) where antifouling coating performance is quickly compromised, or areas where antifouling coatings cannot be applied (e.g. the sections along the keel that the vessel rests on while out of the water). In such ‘niche areas’, biofouling development occurs earlier and at elevated rates compared to regular hull areas (Davidson et al. 2009; Floerl et al. 2010).

Biofouling reduces vessel speed, manoeuvrability, and fuel efficiency, resulting in considerable financial penalties for commercial vessels in particular (Schultz et al. 2011). Most vessel operators therefore arrange for periodic biofouling removal. This can be undertaken in two ways:

1. **In-water cleaning** of fouled hull areas. This is generally undertaken by commercial divers using brush- or waterjet-based tools. Most of these tools (except for novel, state-of-the-art technology used in some large global shipping hubs) are unable to capture all or any of the material removed, which can contain viable organisms or propagules of HAOs. These have the potential to survive and become locally established, depending on the quantity released, type of organism and suitability of the recipient environment (Woods et al. 2007; 2012a). In-water cleaning is for this reason highly regulated in New Zealand and generally prohibited (Morrisey et al. 2015). However, it is at the discretion of local authorities to authorise cleaning events depending on circumstances. Anecdotal evidence obtained by the authors over the past decade indicates that some in-water cleaning takes place nevertheless and 'in secret'.
2. **Shore-based cleaning facilities**. These include dry-docks, slipways, haul-out yards, and tidal grids. In these locations, biofouling removal is generally undertaken using hand-held scrapers, high-pressure waterjets, and brushes. Despite the mechanical stresses (and fresh water) that biofouling assemblages are subject to during land-based cleaning, some survive the process. If cleaning waste (including solids and liquid run-off) are not effectively captured and disposed of on land, the discharge of potentially viable HAOs into coastal waters adjacent to the cleaning facility cannot be ruled out (Woods et al. 2007; 2012a).

Commercial vessels require regular class surveys (to ascertain safety, structural and operational aspects) as part of their registration society membership. Survey intervals generally average 5 years but can be required more frequently or extend to ~8 years for very large modern ships. In some cases, underwater inspections in lieu of dry-docking (UWILD) surveys are allowable between shore-based surveys and these are generally performed by commercial diving teams. Many commercial vessel owners and operators try to align class survey with hull maintenance (i.e. biofouling removal or antifouling renewal) requirements for cost-effectiveness. This can result in some vessels carrying substantial biofouling on their hulls by the time they are maintained (Inglis et al. 2013; Morrisey & Woods 2015). Recreational vessels are generally under no obligation to carry out periodic maintenance[9] and both biofouling removal and antifouling renewal occur at vastly varying frequencies (ranging from months to years) depending on the owner (Floerl et al. 2009).

Both Westport Harbour and the Port of Greymouth have facilities for removing vessels from the water for cleaning and maintenance. Greymouth currently has a slipway suitable for vessels up to 80 dry weight tonnes. It presently services approximately 25

[9] But see Section 2.4.2

vessels per year and has a simple system in place for collecting biofouling or cleaning waste. This slipway is due to be upgraded with a view to increased use and the ability to service larger vessels (Mills 2020). This new upgrade is funded by the Provincial Growth Fund and will accommodate up to 200 dwt vessels with a modernised waste capture system in place (pers comm., Port Team Leader, Grey District Council 2020). Westport also operates a slipway for local vessels. This slipway services approximately five vessels per year and has a maximum capacity of 30 dwt (pers comm., Port Manager, Buller District Council 2020). At Jackson Bay, resident vessels are reported to clean and apply antifoul coating on the foreshore during low tide (pers comm., West Coast Regional Council).

The exact number of occasions during which potentially viable biofouling material is released into the West Coast CMA marine environment via in-water or shore-based cleaning events is unknown. When cleaning is undertaken on local vessels that have not left the region since their last hull maintenance, the biosecurity risk is likely negligible or small, since any organisms on their hulls would have recruited from locally or regionally established populations. However, cleaning of local vessels that have spent periods in ports, marinas or coastal environments outside the West Coast CMA, or of any visiting vessels normally domiciled outside the West Coast CMA, is potentially associated with biosecurity risks and the release of HAOs.

3.3. Coastal infrastructure

Coastal infrastructure such as wharves, seawalls, pontoons, pilings, and breakwaters are usually constructed from rock, concrete, steel, wood or plastic. These artificial materials are appealing settlement substrates that attract marine non-indigenous species (NIS) at an elevated rate compared to natural rocky habitats. On average, approximately 50% of the coastline associated with New Zealand's main urbanised harbours consists of artificial structures. Many of these structures are associated with ports and marinas and, for this reason, are often the first point of establishment and proliferation of HAOs via calling vessels. New Zealand's government-funded port baseline surveys (2000-2008) and target surveillance (MHRSS, ongoing since 2001, visit www.marinebiosecurity.niwa.co.nz for more information) target predominantly artificial infrastructure and have detected many newly established populations of HAOs around New Zealand (Woods et al. 2020).

There is a range of coastal infrastructure types within the West Coast's CMA, primarily located around Westport, Greymouth, and Jackson Bay. They include break walls, wharves, and seawalls associated with port, marina, mooring and fishing facilities, and stabilised coastlines. There are also several boat ramps for trailered vessels throughout the region. A recent (2016) mapping exercise calculated the extent of subtidal artificial surfaces around Greymouth and Westport as approximately 23,000 and 39,600 m^2, respectively (Cawthron, unpubl. data).

Potential biosecurity risks associated with coastal infrastructure occur during both the construction phase (which often involves vessels, equipment and materials sourced from elsewhere that may feature entrained HAOs depending on origin and maintenance state) and the operational phase (maritime construction usually results in increased vessel traffic and visitation rates and offers increased space for colonisation by HMOs) (Floerl et al. 2014). Furthermore, biofouling ‘pressure’ (i.e. the number of organisms available to colonise a hull) is generally greatest in sheltered port and marina environments (Floerl & Inglis 2003).

While we are not aware of all coastal/maritime construction and development initiatives envisaged for the West Coast region, the Government-funded rebuild (Mills 2020) and expansion of port and vessel-maintenance facilities around Greymouth and Westport present relevant examples of ongoing or upcoming activities potentially associated with marine biosecurity risks.

3.4. Dredging and dredge spoil disposal

Most ports and some marinas located in soft-sediment harbours and estuaries utilise capital or maintenance dredging to create or maintain sufficient depth around shipping channels and basins. Dredging is usually carried out by specialised vessels (such as trailing suction hopper dredges) but can at times also involve specialised diggers working from a barge or floating platform.

Dredging presents two possible biosecurity risks:

1. The **origin and nature of the dredge** carrying out the activity. Many dredging programmes are carried out using vessels and equipment sourced from other domestic locations or (for large and complex projects) even overseas. Following the operation of dredging systems, sediments removed from the target area, including epifaunal (inhabiting the seafloor) and infaunal (living beneath the sediment surface) organisms can remain entrained in the dredge itself and within associated vessels or barges. If sufficient seawater is present around entrained organisms or reproductive propagules, survival for days to weeks is possible (Sneddon et al. 2014; Morrisey & Floerl 2018). Relocation of these dredges to new working environments can thus facilitate the transfer of viable organisms, including HAOs, and their accidental release into these locations. As with biofouling waste, chances of local establishment are determined by the types and numbers of organisms released and the suitability of the receiving environment. Dredge vessels are also inherently prone to fouling because (i) they often spend extensive stationary periods in high-fouling port environments, and (ii) they travel at low speeds, which enhances survival of biofouling species (Coutts et al. 2010a; 2010b). If a dredge is locally owned and operated, this type of biosecurity risk does not apply as the organisms entrained would originate from local populations.

2. The **movement of dredge spoil from one area to another** and the alteration of the seabed, potentially increasing habitat suitability for HAOs. Sediment (and associated organisms) removed from one area and discharged as dredge spoil at another location some distance away can facilitate the local or regional transfer of HAOs, including Unwanted or Notifiable species. This type of risk will only be a concern if HAOs are established around dredged areas and if release of dredge spoil occurs at locations where the same HAOs are presently not established and would be unable to disperse to via natural means (Morrisey & Floerl 2018; Fletcher & Johnston 2019). As above, the biology and quantity of organisms released, and the environmental parameters of the recipient location/s determine the chances of survival and establishment. An associated risk of dredging is the disturbance of the seafloor in the targeted area, which can create favourable conditions or 'windows of opportunity' for the establishment of new or expansion of existing HAOs (Sinner et al. 2012; Sneddon et al. 2014; Morrisey & Floerl 2018).

Westport Harbour owns a trailing suction hopper dredge which primarily worked to maintain channel depth for vessels exporting cement from Westport (which occurred approximately twice a week for around 50 years). This operation ceased in 2015, with Holcim leaving Westport in 2016. The Buller District Council still holds a consent for dredging operations. However, in recent years the dredge has predominantly been used for domestic contracts outside of Westport Harbour, carrying out contracts at Greymouth, Nelson, Wellington, and Gisborne (see www.westportharbour.co.nz/port-services.php). Depending on the duration of these contracts and the nature of cleaning and decontamination undertaken prior to the dredge's return to Westport, the presence and use of the dredge in Westport's marine environment could be associated with biosecurity risk. At these ports, some maintenance dredging is likely to take place within the river mouths and the channel to increase the safety of bar crossings for vessels.

It is our understanding that the Port of Greymouth (or council) has owned a dredge for several years, but that this dredge has never been used for its purpose due to critical and yet unresolved defects. As such, it is unlikely to pose any biosecurity risk.

3.5. Marine farming

The majority of the West Coast CMA is largely considered unsuitable for marine farming activities due to the coastline being highly exposed with considerable westerly swells. At the time of writing, there is only one active coastal permit for marine farming within the West Coast CMA. This permit is for a 45.6 ha green-lipped mussel farm, located about one kilometre offshore in Jackson Bay, north of Fiordland. There are currently no structures in the water; however, the consent was issued in June 2004 with a 35-year term so it is possible that farming operations may commence at some point. In addition, recent developments in technology have resulted in marine farming infrastructure engineered to withstand more exposed environments. As such, it is conceivable that marine farming activities could occur in other locations within the West Coast CMA in the future.

Aquaculture operations present several biosecurity risks that can lead to HAOs being translocated between growing areas or regions. Farm-related vessels, equipment/gear, and stock can all harbour HAOs 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. Several previous reports have considered the biosecurity implications associated with aquaculture (e.g. Kelly 2008; Keeley et al. 2009; Zeldis et al. 2010; Hopkins et al. 2011; Forrest & Fletcher 2015; Fletcher & Johnston 2019). 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 the development of aquaculture within the West Coast CMA would involve vector pathways that do not already occur in the region, the associated biosecurity risks could be high.

Movement of farm-related vessels

Vessels used in day-to-day operation of a marine farm are not likely to introduce biosecurity risks from outside the West Coast 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) or from vessels moving inter-regionally for specific purposes such as harvesting. The risks from these vessels will be dependent upon where the vessel has originated, and whether the region of origin has established populations of HAOs not currently present within the West Coast CMA. Risk mechanisms are the same for movements of vessels and structures in general (see Section 2.3.1), aside from ballast water risks, which are not directly relevant to aquaculture operations in New Zealand given that vessels are comparatively smaller and unlikely to require ballast in this industry.

Movement of farm-related equipment

The movement of equipment associated with marine farms (e.g. ropes, floats, nets, etc.), both within and between growing regions, does occur albeit on an infrequent basis. Movement of these items can transport HAOs as biofouling or within associated water or sediments. As with vessel hulls, biofouling assemblages develop relatively quickly on marine farm infrastructure (e.g. Woods et al. 2012b). If this biomass is not removed or rendered inert prior to transfer to another location, the associated biosecurity risk is high (Hewitt et al. 2004). As with farm-related vessel movements, the associated biosecurity risks will largely be dependent on where the transfers originate. Due to the isolation of the West Coast and the comparatively low number of existing vectors (e.g. vessel movements, existing aquaculture operations), the movement of previously used equipment would present a relatively high biosecurity risk to the region[10].

Movement of stock

The transfer of aquaculture stock between areas or regions can lead to associated transfer of HAOs (Sinner et al. 2013). Juvenile shellfish stock (e.g. mussel and oyster spat) are often transported out of water among farms and regions, and more recently from hatchery facilities[11]. The mussel and oyster sectors have procedures that can reduce the risk of transfer of associated pest or HAB species; however, a level of residual risk is likely to remain. The risk from finfish aquaculture largely relates to the water that stock is transferred in. Depending on the source, this water may contain both juvenile (e.g. larvae, algal spores) and adult life stages of macroscopic pests as well as pathogens, parasites, or HAB species. If seaweed culture is progressed in New Zealand, it is expected that juvenile plantlets will be cultured in land-based hatchery facilities and transferred to sea farms for the final grow-out phase. As with shellfish stock transfers, there will be an associated risk of the transfer of HAOs. Like the movement of farm-related equipment, the movement of aquaculture stock would present a relatively high biosecurity risk to the region unless managed appropriately.

Farm-scale biosecurity risks

In addition to aiding the dispersal of pests and diseases, aquaculture operations physically impact the environment within the farm area. Marine farms use complex and extensive structures that provide habitat for fouling organisms. As marine farms are semi-permanent structures, populations of HAOs 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 (Bloecher et al. 2015). In addition, farms may alter their local environment (e.g. by changing water or sediment quality) and create conditions that create or increase biosecurity risks. For example, nutrient enrichment from finfish farms may exacerbate a HAB species that is already established in the region. Similarly, sub-optimal health of cultured stock can lead to proliferation of disease outbreaks which may subsequently spread to wild populations of susceptible species (see Lafferty et al. 2015).

[10] Consent conditions for the marine farm in Jackson Bay specifically state that all materials used on the farm should be new, and no materials previously used outside Jackson Bay should be used in its construction or operation.

[11] Consent conditions for the marine farm in Jackson Bay only allow locally caught spat to be used in the operation of the farm. Producing spat on site negates the risks associated with spat transfers for this farm.

4. RISK MITIGATION OPTIONS FOR THE WEST COAST CMA

There are currently few controls in place to mitigate against the biosecurity risks posed by activities occurring in the West Coast CMA. Proactive prevention is widely accepted as the best biosecurity risk mitigation strategy, with critical aspects being active management of high-risk vectors and routine monitoring of likely points of first establishment (Mack et al. 2000; Inglis et al. 2013; Sinner et al. 2013). Termed 'pathway management', such approaches aim to minimise the likelihood of invasive species introductions in the first instance.

Pathway management recognises the extreme difficulty of eradicating or managing established introduced species in the marine environment (Meyerson & Reaser 2002; Coutts & Forrest 2007) and is being widely adopted in New Zealand at national and regional levels. Adopting a pragmatic pathway management approach could effectively mitigate against biosecurity risks posed to the West Coast CMA itself, as well as contributing to aligned national and regional initiatives throughout New Zealand. By aligning with existing pathway management approaches, the West Coast CMA can play an integral part in strengthening New Zealand's overall biosecurity system. Alignment also provides an opportunity to adopt already developed and well-proven procedures and approaches, rather than starting from scratch.

Examples of aligned regional marine biosecurity rules can be taken from:

- Northland Regional Council (see Northland Regional Pest and Marine Pathway Management Plan pages 100-112),
- Bay of Plenty Regional Council (see the Proposed Regional Pest Management Plan for the Bay of Plenty region pages 26-34 and 46-62)
- Hawke's Bay Regional Council (see Hawkes Bay Regional Pest Management Plan pages 31-33)
- the Top of the South (Island) Marine Biosecurity Partnership (see Marlborough District Council Regional Pest Management Plan pages 54-56)
- Environment Southland (see the Southland Regional Pest Management Plan pages 28-35 and 41-58, and the Fiordland Regional Pathway Management Plan).

Specific requirements vary by jurisdictional focus, but all the above listed initiatives share an overarching pathway management approach that could be adopted for the West Coast CMA. The aims of a nationally and regionally aligned marine biosecurity framework for the West Coast CMA can be divided into five key components:

- **Control entry pathways** – identify and proactively manage high-risk vectors to prevent HAO introductions
- **Protect high-risk and/or high-value areas** – focus effort on areas most likely to be points of first establishment for HAOs (e.g. ports and marinas) and protect

environments most at risk from the impacts of HAOs (e.g. high biodiversity environments (Sinner et al. 2012)

- **Educate and raise awareness –** engage the public and relevant industries to encourage biosecure behaviour[12]
- **Monitor –** undertake baseline surveys of regional high-risk infrastructure and habitats followed by routine surveillance of likely points of first establishment to generate necessary baseline knowledge and for timely detection of HAOs
- **Respond rapidly –** have in place plans and procedures to respond to HAO incursions.

These five components of a marine biosecurity pathway management approach for the West Coast CMA represent best practice marine biosecurity. Their achievement should be considered as a long-term goal, and a pragmatic approach would be staged development and implementation in alignment with other regional jurisdictions. Regardless of whether marine biosecurity measures for the West Coast CMA are regulatory, non-regulatory, enforced, or encouraged, real-world implementation requires risk-specific mitigation actions. The following sections outline risk mitigation options for each of the five main categories of biosecurity risk to the West Coast CMA defined in Section 3.

4.1. Movement of vessels and associated equipment

Mitigation measures for vessels largely rely on good maintenance and regular cleaning, with different requirements for vessels moving into versus within the West Coast CMA.

4.1.1. Movements of vessels into the West Coast CMA

Vessel movements into the West Coast CMA, such as those associated with the hoki and tuna fishing seasons, originate from all around New Zealand and present significant risks of introducing HAOs. Enforced or voluntary guidelines for incoming vessel maintenance and cleanliness are now being implemented by many of New Zealand's regional jurisdictions. Hull and niche area biofouling have been the primary focus of risk mitigation activities for small vessels, but it is also important to consider bilge water, ballast water and associated equipment.

Hull and niche area biofouling

At the national level, the CRMS-BIOFOUL stipulates strict thresholds for biofouling on vessels incoming to New Zealand (see MPI's Craft Risk Management Standard for Biofouling [2018]). The thresholds are tailored for two risk categories. Vessels

[12] There is a recent recognition that awareness raising needs to be replaced by behavioural change campaigns, as increased awareness does not necessarily lead to people changing their ways.

planning to stay in the country for 21 days or longer ('long-stay') can have no more than a slime layer and goose barnacles on the hull. Vessels planning to stay for 20 days or less ('short-stay') are afforded more leniency, with one organism type of either tubeworms, bryozoans, or barnacles at up to 1% coverage of the hull and 5% coverage of niche areas allowable. Comparable thresholds have been adopted for some high-value environments by regional jurisdictions, for example the Regional Coastal Plan: Kermadec and Sub-Antarctic Islands (Department of Conservation 2017) and the Fiordland Marine Regional Pathway Management Plan 2017 (Environment Southland 2017). Threshold-based approaches provide strong regulatory mechanisms, but they can be difficult to interpret in the real world and require significant effort and resources to enforce. As such, most regional jurisdictions managing hull and niche area biofouling have instead opted to encourage or enforce good vessel maintenance and regular cleaning.

The 'six or one' rule has been adopted by several regional councils in New Zealand[13]. Incoming vessels must provide evidence that their hull has been antifouled in the last six months or, alternatively, evidence that it has been cleaned on land within one month. Environment Southland requires all vessels entering the Fiordland Marine Protected area to hold a 'Clean Vessel Pass', whereby vessel owners agree to adhere by best practice vessel maintenance and cleaning standards[14]. It is also worth noting that commercial vessels operating within New Zealand under Safe Ship Management are required to undertake an out of water inspection of the hull and fittings every 2 years and many of these vessels will clean and often professionally reapply antifouling coating to the hull[15].

Bilge water

Management of bilge water is encouraged in some regions, for example, as part of Environment Southland's Clean Vessel Pass. Mitigation options for bilge water risks include restrictions on the location of discharge, retaining bilge water for disposal, or treatment prior to disposal. Given the challenge of enforcing bilge water rules, the most value is likely to come from industry codes of practice and education promoting the discharge of bilge water at its source location and/or treatment options (Cawthron Institute 2013; Fletcher et al. 2017).

Ballast water

Domestic ballast water discharge is difficult to manage due to the short port-to-port movements that make blue water exchange in accordance with the International Convention for the Control and Management of Ships' Ballast Water and Sediments unfeasible. While noting that most domestic vessels incoming to the West Coast CMA are unballasted, some authorities have adopted voluntary measures to mitigate ballast

[13] https://www.marina.co.nz/pdf/TBM-Antifoul.pdf
[14] https://www.es.govt.nz/environment/biosecurity-and-biodiversity/marine-biosecurity/fiordland-marine-pathway-plan#toc-link-6
[15] https://www.maritimenz.govt.nz/commercial/safety/safety-management-systems/default.asp

water risks. For example, Environment Southland has an agreement with the cruise ship industry to not discharge ballast water in the Fiordland Marine Area. A similar approach could be considered and adopted for areas of the West Coast CMA if appropriate.

Associated equipment

Equipment, such as used fishing gear, transported into the West Coast CMA has potential to harbour HAOs. Best practice is to thoroughly clean, treat, and inspect such equipment as free from visible biofouling or other organisms. Again, Environment Southland's Fiordland Marine Regional Pathway Management Plan includes provisions for decontamination of equipment being moved into Fiordland.

Risks posed by vessels moving into the West Coast CMA could be managed by:

- **encouraging or enforcing good maintenance and regular cleaning of hull and niche areas, for example the 'six or one' rule**
- **raising awareness and considering voluntary agreements or codes of practice to ensure bilge and ballast water is discharged at its source location, treated, and/or exchanged in low-risk environments**
- **raising awareness and considering voluntary agreements or codes of practice to ensure equipment such as used fishing gear is cleaned and visibly free of biofouling.**

4.1.2. Movements of vessels within the West Coast CMA

Movements of vessels within the West Coast CMA pose relatively low risk and efforts targeting incoming vessels are likely to have spill over benefits by encouraging good vessel maintenance, cleaning, and behaviour in general. Raising awareness of the biosecurity threats posed by hull and niche area biofouling, bilge water, ballast water, and associated equipment for vessels moving into and within the West Coast CMA would contribute to a stronger overall biosecurity system.

Developing a management plan or approach for vessel movements within the West Coast CMA could also be considered as preparation for a potential HAO incursion. Such forward planning could underpin swift reaction to ring-fence any HAO incursion and maximise the feasibility or likelihood of success of associated response efforts or eradication campaigns.

Risks posed by vessels moving within the West Coast CMA could be mitigated by:

- **raising awareness of biosecurity risks and encouraging good vessel maintenance, cleaning, and behaviour**
- **considering a pre-emptive management plan or approach for intra-regional vessel movements to underpin rapid response to a HAO incursion.**

4.2. Vessel cleaning and maintenance

Although vessel cleaning can optimise performance and minimise biosecurity risks, it can also result in environmental contamination and facilitate the spread of HAOs if not properly managed (Scianni & Georgiades 2019). Shore-based cleaning of vessels poses proportionally less risk than in-water cleaning and the availability of appropriately sized slipway/dry-dock facilities and travel hoists with sumps could greatly simplify the management of vessel cleaning and maintenance in the West Coast CMA. Containment, capture, and disposal of waste on land will avoid the release of HAOs or chemical contaminants to the marine environment (Morrisey et al. 2013; 2015; Morrisey & Woods 2015).

If in-water cleaning is to occur, The Antifouling and In-water Cleaning Guidelines 2015 provide best practice guidance for regional councils consistent with the Coastal Policy Statement 2010. Work is ongoing at a national level to refine protocols and evaluation criteria for in-water cleaning and capture systems for hull and external niche areas (Morrisey et al. 2015, 2016; Morrisey & Woods 2015), as well internal niche areas such as pipework and sea chests (Growcott et al. 2016, 2017; Cahill et al. 2019a; 2019b; Growcott et al. 2019). Future improvements are likely to include choosing the correct antifouling coating, defining cleaning practices appropriate for different antifouling coating types, and region-specific guidance of regulatory options and infrastructure needs (Forrest & Floerl 2018).

Risks posed to the West Coast CMA by vessel cleaning could be mitigated by:

- **primarily encouraging and enabling shore-based cleaning and maintenance options, with all waste captured and disposed on land**
- **managing in-water cleaning in accordance with Antifouling and In-Water Cleaning Guidelines 2015, and future amendments thereof.**

4.3. Coastal infrastructure

Options to mitigate risks from coastal infrastructure in the West Coast CMA could be considered for both new and existing infrastructure. New infrastructure development projects provide an opportunity to consider marine biosecurity from the outset, and options exist for infrastructure to be designed in ways that avoid or reduce the establishment and proliferation of pest species. Eco-engineering principles are beginning to be applied for coastal infrastructure developments (see Schaefer et al. 2020) and could be considered for the West Coast CMA. During construction of coastal infrastructure, all materials should be new or have been appropriately treated to kill or remove marine organisms they may harbour. Treatment options for used construction materials range from chemical disinfection to simple air-drying (Forrest et al. 2007; Atalah et al. 2016; Georgiades et al. 2016; Morrisey et al. 2016; Joyce et al.

2019). All vessels used for construction activities should also adhere to best practice maintenance and cleaning guidelines (see Section 4.1).

Existing coastal infrastructure in the West Coast CMA is extensive and likely presents the highest risks as point of first establishment for HAOs. Modifying or retrofitting existing infrastructure to reduce the likelihood of HAO establishment is possible but would require significant initial research and development. It is likely to incur significant cost and is unlikely to be realistic in the short to medium term. Baseline surveys followed by routine monitoring of infrastructure for HAOs in ports or locations receiving vessels from outside the West Coast CMA is a realistic option that would significantly enhance the likelihood of early detection of an incursion. In line with Marine High-Risk Site Surveillance activities (Inglis et al. 2006; Woods et al. 2020), regular diver surveys of port and marina infrastructure could provide baseline and ongoing knowledge of the West Coast CMA's biosecurity status.

Regular surveillance activities could be targeted at HAOs most likely to be introduced and establish in the West Coast CMA. Such an approach could be supported by species distribution and habitat suitability models that are being prepared for a range of HAOs already present, or at risk of arriving, in New Zealand. Recent advances in molecular technology mean that monitoring can now be undertaken using genetic (environmental DNA) approaches and do not necessarily need to rely on divers or trapping (Pochon et al. 2015; Zaiko et al. 2015; 2016; von Ammon et al. 2018; Wood et al. 2019).

Risks posed to the West Coast CMA by coastal modification and infrastructure could be mitigated by:

- **considering eco-engineering principles in the design of new infrastructure developments to reduce the likelihood of HAO establishment**
- **ensuring infrastructure developments use new or appropriately treated construction materials, and vessels adhere to best practice maintenance and cleaning guidelines**
- **undertaking baseline and routine surveillance of coastal infrastructure in likely points of first establishment to generate baseline knowledge and for early detection of any incursions.**

4.4. Dredging and dredge spoil disposal

Risk mitigation options should consider both dredge vessels and dredge spoil. Dredges that reside within the ports they dredge likely require minimal scrutiny. However, an existing dredge vessel from Westport undertakes contracts around New Zealand, and as such should adhere to best practice guidelines for maintenance and cleaning (Section 4.1). Any new dredging activities in the West Coast CMA should also comply with best practice.

Dredge spoil typically originates from port environments and as such has elevated risk of containing HAOs. Knowledge of the biosecurity status of source environments is key to ensuring dredge spoil disposal is biosecure. If ports are confirmed free of pests then there is little biosecurity concern related to dredge spoil disposal. In line with Section 4.3, baseline and on-going monitoring of ports is the best mitigation approach. As an additional precaution against HAOs that have recently established or gone undetected for some time, dredge spoil should be discharged in areas of lower biodiversity value and with environmental conditions that are unfavourable for HAOs (i.e. away from rocky substrate and in high-energy environments) or discharge close to the source of the dredge spoil.

Risks posed to the West Coast CMA by dredging and dredge spoil disposal could be mitigated by:

- **ensuring dredge vessels adhere to best practice maintenance and cleaning guidelines**
- **monitoring biosecurity status of dredge spoil source ports and disposing of dredge spoil in areas of low biodiversity value and with environmental conditions unfavourable for HAOs.**

4.5. Marine farming

While marine farming can play an important role in the spread of HAOs, the industry has a strong incentive to manage risks to the extent that is feasible and affordable, because cultured species can be particularly vulnerable to adverse effects from some HAOs (Sinner et al. 2012). No marine farming currently occurs in the West Coast CMA, but it could occur in the future and biosecurity mitigation measures would need to be applied. Aquaculture New Zealand's A+ Sustainable Management Framework provides detailed biosecurity guidelines for green-lipped mussel, chinook salmon, and Pacific oyster farms[16], and a Government Industry Agreement between industry and MPI provides a mechanism for joint decision-making and cost sharing for biosecurity readiness and response activities[17]. MPI has also published detailed technical guidance for biosecurity mitigation measures for marine faming (Georgiades et al. 2016; MPI 2016b; Sim-Smith et al. 2016). A high level overview of best practice biosecurity mitigation measures is provided below for the four risk categories described in Section 3.5.

[16] Available from: http://www.aplusaquaculture.nz/#frameworks
[17] https://www.biosecurity.govt.nz/protection-and-response/biosecurity/government-industry-agreement/

Movement of farm-related vessels

As with all vessel movements, good maintenance and cleaning are effective in mitigating biosecurity risks (Section 4.1). Given the heightened risks and consequences of HAO in aquaculture scenarios, all farm vessels should adhere to high biosecurity standards even when operating within regions. Ensuring antifouling systems are up to date, monitoring for biofouling growth, and regular maintenance is recommended. More stringent biosecurity practice should be in place for those vessels that operate between farms, regions and/or multiple high risk sites (e.g. different ports), and this management could follow the 'six or one' rule described in Section 4.1.

Movement of farm-related equipment

Moving gear between farms should be avoided but it does occur as part of normal farming practice; for example, culture ropes used in green-lipped mussel aquaculture are often reused and moved. If used gear is moved into or within the West Coast CMA, it should be thoroughly cleaned, detailed records kept, and treatments applied if necessary. Treatment techniques appropriate for use on aquaculture gear include air drying, immersion in fresh water, and immersion in acetic acid or bleach (Georgiades et al. 2016).

Movement of stock

Ideally stock should be sourced or grown onsite, for example by catching wild green-lipped mussel spat on ropes deployed on-farm. However, it is often not feasible to source stock locally and it is likely that aquaculture would involve moving stock into and within the West Coast CMA. The primary option to mitigate against the risks of stock movements is assurance of the 'clean' biosecurity status of source hatcheries, farms, or environments. There are also some specific measures to treat stock prior to movement; for example, the National Spat Transfer Programme provides transfer protocols, record keeping requirements, and guidelines for applying treatments to mitigate risks of harmful micro-algae associated with green-lipped mussel spat transfers (New Zealand Mussel Industry Council 2002).

Farm-scale biosecurity risks

Impacts on the physical environment and potential effects from provision of new habitats are typically considered during consenting of marine-farm activities. It is, however, unavoidable that aquaculture will provide some additional habitat and conditions for HAOs to potentially establish and proliferate. Regular monitoring for HAOs on farm infrastructure and crop can mitigate against this risk. Farm personnel should become familiar with relevant species in the MPI 'New Zealand's Marine Pest Identification Guide'. Under Sections 44 and 46 of The Biosecurity Act 1993, there is a legal obligation to report *the presence of what appears to be an organism not normally seen or otherwise detected in New Zealand* or any organism listed on the

Notifiable Organisms Database. Reporting should be done via the MPI Exotic Pest and Disease Hotline (0800 80 99 66) as soon as practicable[18].

Any cleaning of existing farm infrastructure (e.g. floats, ropes, nets) should be undertaken on site. Cleaning on site ensures biofouling and sediment are released within the permitted area and helps prevents the transfer of species between areas.

Risks posed to the West Coast CMA by marine farming could be mitigated by:

- **ensuring farm vessels are well maintained, monitored for biofouling, and regularly cleaned**
- **avoiding movements of farm-related equipment or appropriately disinfecting prior to movement**
- **ideally sourcing stock locally, but if stock needs to be transferred into or within the West Coast CMA ensure 'clean' biosecurity status prior to transfer and apply culture species-specific measures**
- **undertake regular on-farm monitoring for HAOs and ensure cleaning of equipment is undertaken onsite.**

[18] https://www1.maf.govt.nz/uor/searchframe.htm

5. ASSESSMENT OF RISKS AND MITIGATION OPTIONS FOR THE WEST COAST CMA

Our qualitative assessment of biosecurity considerations for the West Coast CMA has defined risks related to vessel movements, vessel maintenance and cleaning, coastal infrastructure, dredging, and marine farming (Section 3). Mitigation options consistent with other regional initiatives in New Zealand were subsequently described (Section 4), and Table 3 provides an overview of the assessment before and after mitigation options are in place. The costs of any given HAO incursion has previously been estimated to be high (Section 2.1) and the overall potential for negative ecological, economic, and cultural effects of HAOs are clear (Forrest & Atalah 2017; Soliman & Inglis 2018). However, the exact type and magnitude of HAO impacts can be highly variable and are dependent on the organism, the recipient habitat, and values associated with invaded locations. For the West Coast CMA, this inherent variability is compounded by a current paucity of detailed knowledge of baseline biosecurity status, habitat susceptibility, and vector pathways.

As such, a precautionary approach (Rio Declaration 1992) was adopted when qualitatively assigning risk components according to criteria modified from Burgman (2005) and EIANZ (2018).Consequence was apportioned into ‘spatial scale’ and ‘magnitude’ by assessing available literature and local information, and discussing scenarios with biosecurity scientists. To account for the limited specific information for the West Coast CMA, the likelihood of effects occurring was assumed to be ‘high’ in all assessments. Judgements related to the ‘consequence’ component of risk could reasonably be extrapolated from experiences from other regions of New Zealand and are estimated for both ‘spatial scale’ and ‘magnitude’ components thereof. Post-mitigation residual levels of risk assignments are descriptive and are based on the authors’ best professional judgement.

When no biosecurity risk mitigation measures are in place, the spatial scale of potential effects ranges from ‘Small’ to ‘Large’ but the magnitude of potential effects for all 9 risk mechanisms is ‘Moderate’ or ‘High’ (see definitions in Table 3). Although these unmitigated risk consequences are substantial, implementing the recommended mitigation options (presented in Section 4) reduces the level of risk to low in the majority of instances. These outcomes assume risk mitigation actions are fully implemented and it is acknowledged that real-world implementation is complex and perfect uptake is unrealistic. The aim of any such system is to reduce, rather than eliminate, risk. Regardless, the assessment outcomes in Table 3 demonstrate why proactive management of biosecurity risks has emerged as the primary tool for regional biosecurity in New Zealand.

Of the range of potential mitigation options outlined, most relate to managing vector pathways associated with vessels, structures, or equipment moving into or within the

West Coast CMA. Vessel movements are arguably the most important pathway for marine biosecurity overall, both in terms of relative frequency of movements and connectivity to New Zealand's domestic 'network' of potential HAO source and establishment locations. As such, vessel biofouling and ballast water are the focus of most international, national, and regional marine biosecurity policy and legislation (Georgiades et al. 2020; examples include IMO guidelines, CRMS-BIOFOUL and Northland Regional Council's Pest and Pathway Management Plan). As a starting point, a primary focus on vessel pathway management for the West Coast CMA likely presents the best potential gains for biosecurity risk reduction. Subsequent, or aligned, activities to address other vector pathways would act to further reduce risk. Of these other vectors, aquaculture activities should be afforded close attention. Aquaculture does not currently occur in the West Coast CMA, but any future activities would significantly alter overall biosecurity risk status and mitigation measures should be implemented for any aquaculture developments.

In addition to managing vector pathways, baseline studies, and monitoring surveys for HAOs in high-risk and high-value environments in the West Coast CMA will contribute to addressing several of the risk mechanisms. Such surveys would provide baseline knowledge of the biosecurity status of the West Coast CMA and increase the likelihood that HAO incursions are detected early. Timely detection of incursions enables rapid response, which significantly improves the likelihood that any eradication or containment attempts will be successful. Monitoring could also provide a better understanding of HAO susceptibility. For example, analysing monitoring data via species distribution modelling approaches can predict which HAOs are able or likely to establish in the West Coast's estuarine ports. This information could underpin more precise biosecurity risk assessments for the West Coast CMA.

Table 3. Marine biosecurity risk mechanisms and potential levels of effect for harmful marine organisms (HAOs) in the West Coast Coastal Marine Area (CMA) before and after mitigation options are put in place. The unmanaged and managed residual level of risk were evaluated via a round-table discussion involving the Cawthron Institute marine biosecurity team. In the absence of actual scenarios, we have adopted the precautionary principle by assuming a high likelihood that these particular risk impacts could occur. We have also assumed the risk mitigation will occur and that this will be monitored by industry and government or a third party.

			Pre-mitigation				Post-mitigation
	Mechanisms of risk	**Potential effect**	**Spatial scale of effect**	**Magnitude of effect**	**Consequence of effect (descriptive)**	**Mitigation option**	**Outcome of risk mitigation (descriptive)**
Vessel movements	Movements of vessels into CMA	HAO(s) introduced to and establishes in CMA	Small[1]	High	HAO introduction has negative downstream effects for a range of economic, ecological, and cultural values	• Good maintenance and regular cleaning of hull and niche areas • Ballast and bilge water discharged at source location, treated, and/or exchanged in low-risk environments • Equipment cleaned and visibly free of biofouling	Proactive pathway management of incoming vessels will substantially reduce the risk of transporting new HAOs into the West Coast CMA
	Movements of vessels within CMA	HAO(s) spreads within CMA	Large	Moderate – High[2]	HAO spread exacerbates effects across CMA and increase risks to areas outside ports	• Raising awareness of good vessel maintenance, cleaning, and behaviour • Pre-emptive management plan or approach for intra-regional vessel movements	Ensuring local vessels follow best practice maintenance and cleaning will minimise the risk of HAOs spreading from vessel hub areas
Vessel cleaning and maintenance	Discharge of cleaning waste	HAO(s) establishes in immediate environment	Small	Moderate – High[3]	HAO introduction or spread to new locations in CMA has effects for a range of economic, ecological, and cultural values	• Shore-based cleaning and maintenance options encouraged • In-water hull cleaning occurs in accordance with Antifouling and In-Water Cleaning Guidelines 2015	Easy to use and affordable shore-based cleaning facilities encourage proactive hull management, whilst capturing biofouling waste to minimise biosecurity risk Ensuring any in-water cleaning adheres to best practice minimises risk of inadvertent HAO release
Coastal infrastructure	Used construction materials moved into or within CMA	HAO(s) transported into or within CMA	Small – Large[4]	High	HAO introduction or spread to new locations in CMA has effects for a range of economic, ecological, and cultural values	• Construction materials are new or appropriately treated • Construction vessels adhere to good maintenance and cleaning guidelines	Ensuring materials are new or appropriately treated and vessels are proactively maintained and regularly cleaned means construction will pose negligible biosecurity risk
	Habitat modification and provision of novel habitat	HAO(s) establish in otherwise unsuitable location	Small	Moderate	HAO establishing on artificial structures impacts immediate area and acts as 'reservoir' for further spread	• Routine surveillance of coastal infrastructure in likely points of first establishment • Eco-engineering principles applied in the design of new infrastructure developments	Although risks are small and incremental over existing infrastructure, routine monitoring will provide assurance of biosecurity status and eco-engineering can reduce HAO establishment likelihood
Dredging	Dredge vessel movements into or within CMA	HAO(s) transported into or within CMA and establish or spread	Small – Large[5]	Moderate-High	HAO introduction or spread to new locations in CMA has effects for economic, ecological, and cultural values	• Dredge vessels adhere to good maintenance and cleaning guidelines	Proactively maintaining and cleaning dredge vessels will minimise the risk of new species establishing or spreading within the West Coast CMA
	Translocation of dredge spoil	HAO(s) translocated from port to natural environments	Medium	Moderate	HAO establishing in environment magnifies scale of effect, particularly on ecological values	• Monitor biosecurity status of dredge spoil sources • Dispose of dredge spoil in areas of low biodiversity value and with environmental conditions unsuitable for HAOs or in areas that are close enough for HAOs to disperse to naturally	Monitoring source locations will help prevent transfer of HAOs with dredge spoil and discharging dredge spoil in suitable locations reduces likelihood that any undetected HAO will survive
Marine farming	Movement of vessels into or within CMA	HAO(s) transported into or within CMA	Small – Large[6]	High	HAO introduction or spread to new locations in CMA has effects for economic,	• Ensure farm vessels are well maintained, monitored, and regularly cleaned	Proactive management of aquaculture vessels, equipment, and stock minimises the risk of HAO

			Pre-mitigation				Post-mitigation
	Mechanisms of risk	**Potential effect**	**Spatial scale of effect**	**Magnitude of effect**	**Consequence of effect (descriptive)**	**Mitigation option**	**Outcome of risk mitigation (descriptive)**
Marine farming, cont.	Movement of equipment into or within CMA	and establish or spread			ecological, and cultural values	• Avoid moving farm-related equipment or appropriately disinfect prior to moving	entering and/or spreading within the West Coast CMA
	Movement of stock into or within CMA					• Source stock locally, only move stock with 'clean' biosecurity status, or apply measures specific to the cultured species	
	Provision of novel habitat or changes to local environment	HAO(s) establishes in otherwise unsuitable location	Small	Moderate	HAO establishing on artificial structures impacts immediate area and acts as 'reservoir' for further spread	• Regular on-farm monitoring for HAOs and cleaning of equipment onsite	Routine and regular on-farm monitoring will ensure any HAO is rapidly detected, allowing timely response to protect both farms and the surrounding environment

Spatial scale of effect:	Small (confined to area of activity, such as a port <1 km), Medium (impacts immediate environment 1 – 10 km), Large (impacts wider region or across regions > 10 km)
Magnitude of effect:	Negligible (no or very slight change from existing conditions/ effect too small to be discernible or of concern), Low/Minor (minor change from existing conditions/noticeable but unlikely to cause any significant adverse effects other than to the activity itself), Moderate/Medium (loss or alteration to key element(s) of existing conditions/noticeable and may cause adverse impacts outside the activity but is temporary or recoverable), High (major or total loss of key element(s) of existing conditions/ noticeable and will have serious adverse impact that is likely to be long lasting and unrecoverable)
Assumptions/explanatory:	1. Although vessel movements are significant pathways for transporting marine organisms to new environments, the immediate impact of a new HAO introduction via vessel movements impacts a 'small' area of primary establishment. Subsequent downstream effects can impact 'large' spatial scales but that is covered separately in various other risk categories presented in this table. 2. Movement of local vessels is unlikely to add new biosecurity risk to the West Coast CMA, however, movements from vessel hubs (e.g. ports) could facilitate the spread of undetected organisms across various spatial scales. 3. Cleaning of local vessels will only present 'moderate' risk but cleaning a fouled vessel originating from outside the region (in-water or out of water without waste capture/treatment) will present 'high' biosecurity risk. 4. The spatial scale and magnitude of the effect of artificial habitat will depend on the type/scale and location of activity. 5. Spatial scale and magnitude of effect of dredge vessels will depend on the activity and the location of where the dredge vessel originates. 6. Spatial scale and magnitude of effect will be based on the extent of farming activities and how quickly any HAO incursion is identified.

6. SUMMARY AND RECOMMENDATIONS

The foundational assessment of the marine biosecurity status of the West Coast CMA undertaken here has highlighted a range of potential risks but also a current lack of detailed knowledge. This lack of knowledge is not uncommon in marine biosecurity (indeed, it is arguably the norm), necessitating precautionary yet adaptable risk mitigation approaches. As such, a series of best practice mitigation options have been defined based on approaches being implemented by other regional councils in New Zealand.

6.1. Implementing marine biosecurity for the West Coast CMA

A pathways approach to marine biosecurity includes more than just regulatory rules on vessel movements. The pathway management approach is a package that includes enforcement if required but also education and awareness, voluntary codes of practice by industry and other groups, and surveillance and the ability to respond to incursions. Examples include promoting best practice marine biosecurity management across risk pathways and activities (see Section 3), developing codes of practice with the shipping industry for ballast water management or visits to high-value environments, and all based on an understanding of HAO status and risks via baseline and monitoring assessments.

A range of regulatory and non-regulatory mechanisms exist to implement regional marine biosecurity. Actively enforcing regulatory mechanisms requires dedicated resourcing, and most other marine biosecurity initiatives in New Zealand have either had staged implementation or rely on public awareness and voluntary engagement. Education and awareness campaigns targeting the public and specific industries, in combination with specific activities to elicit behavioural change, can improve biosecurity outcomes. Some options for the marine context were recently prepared by the Cawthron Institute (Newton 2019) under contract to Auckland Council and following a survey of stakeholders. At least as a starting point for the West Coast CMA, behavioural change campaigns could be considered that highlight the risks posed to the region and outline easily achievable mitigation measures. All relevant interests and stakeholders should be included, and campaigns could include anything from workshops with industry to informal and formal consultation during plan making.

If regulatory options are to be pursued for marine biosecurity in the West Coast CMA, the New Zealand Coastal Policy Statement 2010 outlines an integrated and proactive pathways approach to marine biosecurity that should be considered for the West Coast Coastal Plan (refer to the Policy 12 Guidance Note Department of Conservation 2019). The Biosecurity Act 1993 provides a range of legislative tools, including underpinning of regional council pest management plans, some of which include marine pests. The Resource Management Act 1991 (particularly sections 12 and 15) and the Resource Management Amendment Act 2020 provide legislative control of a range of activities relevant to marine biosecurity, including:

- introduction of structures
- discharge or disposal of organic material (including biofouling)
- provision and ongoing maintenance of coastal infrastructure
- establishment and relocation of aquaculture equipment and stock
- other activities including relocation of vessels, mooring equipment, and fishing gear, use of special equipment for one-off purposes and events.

These pieces of legislation could be invoked to enforce marine biosecurity for the West Coast CMA by providing a complementary suite of regulatory mechanisms.

6.2. Inclusion of mana whenua

The consideration of biosecurity risks, and development and prioritisation of risk mitigation approaches should be pursued in collaboration with mana whenua of the West Coast CMA. Prior initiatives, such as the pathways plan developed for the Fiordland region show how the recognition and incorporation of Māori values can result in a holistic approach that is met with wide-ranging support and uptake. Traditional knowledge is also a valuable source of information for incorporation into baseline and status assessments associated with HAOs and regional values.

6.3. Integrating with other regional biosecurity initiatives

Leveraging existing institutional knowledge presents a simple pathway toward marine biosecurity management for the West Coast CMA. Integrating marine biosecurity pathway management with other regional jurisdictions would also ensure efficient, complimentary, and effective management of HAOs by minimising inconsistencies between and within approaches, policies, and regulations.

A key recommendation of this report is for the West Coast Regional Council to engage with their marine biosecurity counterparts at other regional councils. Current (as of writing these report) contacts and useful documents are provided in Appendix 2, and leading agencies and groups include:

- Top of the South Marine Biosecurity Partnership
- Environment Southland and the Fiordland Marine Biosecurity partnership
- Top of the North Marine Biosecurity Partnership.

The Top of the South and the Fiordland Marine Biosecurity partnerships are examples of effective collaboration in marine biosecurity, and both border the West Coast CMA.

Exploring avenues for collaboration and information sharing relating to biosecurity management with these and other regions would be a useful starting point for building capability and addressing HAO risks to the West Coast CMA.

6.4. Further research and development requirements

While this report has provided a foundational assessment for marine biosecurity in the West Coast CMA, generating additional specific knowledge and data would address current uncertainty for more precise risk assessment and tailoring of mitigation activities. Research and development recommendations include:

- baseline and ongoing surveys for HAO in high-risk locations, notably the ports of Westport, Greymouth, and Jackson Bay
- species distribution modelling to predict which HAO are of most concern to the West Coast CMA given that the primary ports are river ports with low salinity and high sediment load
- monitoring of vessel movement not covered by AIS tracking into and within the West Coast CMA.

In addition to providing a more complete picture of current risks and the most appropriate mitigation measures, information generated could help define high-value areas most at risk from HAO and underpin the development of incursion response strategies.

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9. APPENDICES

Appendix 1. Fisheries NZ information on fishing vessel movements for hoki, tuna, lobster, and ACVs.

Fisheries New Zealand
Tini a Tangaroa

OIA20-0246

5/06/2020

Shaun Cunningham
shaun.cunningham@cawthron.org.nz

Dear Shaun Cunningham

OFFICIAL INFORMATION ACT REQUEST

Thank you for your email of 7 May 2020 requesting information relating to vessel movements on the west coast of the South Island. Your request has been considered under the Official Information Act 1982 (OIA).

Please note that the count of individual vessels is not representative of the number of fishing events or trips that have occurred during this period.

You requested the following:

1. *Vessels going to west coast ports for hoki season ~May-July and where they come from/usually operate.*

For the 2019 calendar year, a total of eight individual vessels targeting hoki reported landing catch in the ports of Greymouth and Westport during the months of May 2019 to July 2019.

Of the eight vessels above, three are based in Greymouth, three in Nelson, one in Westport and one in Lyttelton.

2. *Vessels going to west coast ports for tuna season ~Jan-March and where they come from/usually operate.*

A total of 86 individual vessels targeting albacore and skipjack tuna reported landing catch in the ports of Greymouth and Westport during the months of January 2019 to March 2019.

Appendix One has the vessel numbers, by region, of where these vessels are based from.

3. *Number of cray boats fishing between Jackson Bay and Fiordland.*

For the 2019 calendar year, a total of 36 individual vessels targeting rock lobster reported having fished between Jackson Bay and Fiordland.

4. Any amateur charter vessels that come and go from the region.

For the 2019 calendar year, a total of 40 individual amateur charter vessels reported having fished, or departed from a port (used where positional information was not available), within the entire west coast region of the South Island.

Fisheries New Zealand has prepared this report on the basis of information provided to it in returns provided by fishers. Fisheries New Zealand does not accept responsibility for the completeness or accuracy of the information on which this report is based.

You have the right under section 28(3) of the OIA to seek an investigation and review by the Ombudsman of our decision.

Yours sincerely

Charlotte Austin
Director Fisheries Science and Information

Appendix 1: Vessel numbers, by region for tuna vessels on the west coast for question 2.

Base Region	Number of vessels
Auckland	2
Bluff	1
Castlepoint	1
Fiordland	3
Golden Bay	5
Greymouth	15
Invercargill	1
Mangonui	1
Mercury Bay	5
Motueka	3
Napier	5
Nelson	21
New Plymouth	1
Picton	1
Raglan	1
Tauranga	1
Timaru	1
Wellington	4
Westport	9
Whangarei	3
Whangaroa	2
Grand Total	**86**

Appendix 2. Table of key biosecurity practitioners within New Zealand.

Contact	Group	Affiliation	Email address
Peter Lawless	Top of the South Marine Biosecurity Partnership	Top of the South Marine Biosecurity Partnership	tosmarinebio@gmail.com www.marinebiosecurity.co.nz
Rebecca McLeod	Fiordland Marine Biosecurity Partnership	Fiordland Marine Guardians	info@fmg.org.nz
Rob Win	Fiordland Marine Biosecurity Partnership & Southland management	Environment Southland	Rob.win@es.govt.nz
Samantha Happy	Top of the North Marine Biosecurity Partnership & Auckland management	Auckland Council	Samantha.happy@aucklandcouncil.govt.nz
Kathryn Lister	Top of the North Marine Biosecurity Partnership & Northland management	Northland Regional Council	Kathryn.lister@nrc.govt.nz
Jen Brunton	Fiordland Marine Biosecurity Partnership	Biosecurity New Zealand	Jen.brunton@mpi.govt.nz
Elizabeth Green	Top of the North and South marine biosecurity partnerships	Biosecurity New Zealand	Elizabeth.green@mpi.govt.nz