Managing the Domestic Spread of Harmful Marine Organisms

Part A - Operational tools for Management

Prepared for Preparedness & Partnerships Directorate, Ministry for Primary Industries

Authors/Contributors:
Graeme Inglis, Don Morrisey, Chris Woods (NIWA), Jim Sinner and Mark Newton (Cawthron Institute)

For any information regarding this report please contact:

Graeme Inglis
Principal Scientist
Marine Biodiversity & Biosecurity
+64-3-343 8036
graeme.inglis@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
10 Kyle Street
Riccarton
Christchurch 8011
PO Box 8602, Riccarton
Christchurch 8440
New Zealand

Phone +64-3-348 8987
Fax +64-3-348 5548

NIWA Client Report No: CHC2013-150
Report date: 12 December 2013
NIWA Project: RFP15830

Cover image: *Ballast water discharge. [Chris Woods, NIWA]*

Contents

Tables

Appendices

Figures

Approved for release by

Dr Barb Hayden

Executive summary

Amendments to the Biosecurity Act 1993 (BSA) in November 2012 created more scope for measures to manage the spread of harmful marine organisms in New Zealand. The Ministry for Primary Industries (MPI) commissioned the National Institute of Water and Atmospheric Research (NIWA) and the Cawthron Institute (Cawthron) to undertake a review of practical measures for reducing the spread of potentially harmful marine organisms via human transport pathways within New Zealand, and policy options for promoting the implementation of risk reduction measures.

During two workshops held in Wellington in 2013, representatives of the aquaculture, commercial fishing, marine transport, mining and exploration, research and education, and sport and recreation pathways were invited to identify and discuss risk reduction options and potential barriers to their implementation. The aim was to engage industry, government, tangata whenua, councils, and other stakeholders in the development of a recommended package of measures and policies for reducing the domestic spread of harmful marine organisms within New Zealand.

The project resulted in two reports. This report describes the nature of the biosecurity risk in six sectoral pathways, including how harmful species can be spread within each pathway ("modes of infection", Table 1-1), and identifies practical measures that could be taken to reduce this risk. A companion report (hereafter referred to as the 'Part B report') assesses policy options and presents recommendations for six different modes of infection across the pathways.

Table 1-1. Modes of infection by sector pathway. (√= mode of infection applies to most activities in the sector. * = mode of infection applies to relatively few activities in the sector).

	Sector pathway					
Mode of infection	**Maritime Transport[1]**	**Mining & Exploration**	**Commercial Fishing**	**Aqua-culture**	**Recreation & Sport[2]**	**Research & Education**
Ballast water	√	√	*			*
Bilge[3]	√	√	√	√	√	√
Hull fouling	√	√	√	√	√	√
Gear	*	√	√	√	√	√
Livestock[4]& bait			*	√	*	*
Structures[5]	√	√	√	√	√	√

[1]Includes merchant ships, barges, cruise ships, ferries and water taxis
[2]Includes customary and recreational fishing
[3]Includes water retained on deck
[4]Includes harvested fish and other organisms that may be dead
[5]Includes moveable structures such as marine farms and swing moorings

Each option is assessed for its effectiveness, feasibility, cost and likely rate of uptake. Given the breadth of this report and the available budget, these assessments are based on limited information and should be seen as preliminary only. In many cases, the performance of a measure on any one of these criteria is likely to vary considerably across different sectors. Further investigation and consultation is therefore recommended prior to implementing such measures.

Biosecurity management is most cost-effective when it aims to reduce the risk of spread at scales greater than what organisms could achieve by natural spread within, for example, a 5-year time frame. This project aims to address risk primarily at an inter-regional scale, but also to inform risk management measures at a more local level. Although regional council boundaries have little or no ecological significance in the coastal marine environment, they can in some cases provide useful boundaries for implementation of biosecurity measures.

The biosecurity regime in New Zealand is governed primarily by the Biosecurity Act 1993. Under that Act, pest management plans, pathway management plans, controlled area restrictions and unwanted organism declarations are among the tools available to central and regional governments to manage the spread of harmful marine organisms. The Resource Management Act 1991, and associated regulations and policy statements, also provides authority for measures, especially with regard to discharges to the coastal marine environment, that can be used to manage harmful marine organisms. Subject to further legal analysis, it appears that existing legislation provides sufficient statutory authority for all of the regulatory measures contemplated in this report. Such measures must still, of course, be justified under the criteria and processes set out in the relevant legislation.

Descriptions of the pathways and recommendations for management of risk for each pathway and mode of infection follow.

Maritime transport pathway

The maritime transport pathway involves the domestic movement of cargo and people by New Zealand-registered and foreign merchant shipping. It also includes movement within New Zealand of passenger vessels, slow-moving barges, dredges and other non-trading commercial vessels (e.g., tugs, tenders, pilot vessels, cargo barges, marine safety vessels, ferries, etc.). Transport of harmful marine organisms by maritime shipping can occur through uptake in ballast water, as biofouling attached to submerged surfaces of the vessels, in bilge or seawater used for ship-board operations, as contaminants picked up unintentionally during retrieval of maritime equipment (e.g., anchors, chains, mooring ropes, etc.) and as contaminants picked up unintentionally in material removed from the seabed (e.g., dredge spoil).

Ballast water

Options for treating ballast water include exchange of coastal ballast water for low risk mid-ocean water, ship-board installation of approved ballast water treatment systems or direct chemical treatment prior to discharge. While exchanging a vessel's ballast water mid-ocean is required of international vessels to reduce the risk of transporting unwanted organisms to New Zealand, it is only partially effective and is not practical on most voyages within New Zealand due to their short duration. Treatment of ballast water has been endorsed by the International Maritime Organisation (IMO) as the best option for international shipping in the medium to longer term. For managing domestic spread within New Zealand, requiring vessels to retrofit with ballast water treatment facilities to meet the IMO standard would be costly and difficult to justify prior to international implementation (i.e., entry into force of the IMO standard). Such a requirement could be initiated some time subsequent to international implementation (e.g., after a further five years to allow more time for adapting the existing fleet).

Another option would be for New Zealand to require treatment but to a lesser standard if, for example, considerable risk reduction can still be achieved but at much lower cost. Further investigation and consultation with the relevant sectors is required to assess the costs of ballast water treatment options and the degree of risk reduction that could be achieved. These factors will largely determine the degree of uptake by domestic shipping and therefore the risk reduction that would be achieved by such an approach.

Bilge water

Options for managing risks from bilge water include discharge and emptying of water before departing from a location, retention and storage of water for discharge to shore-based treatment, installation of an approved filtration system, regular flushing with freshwater or an approved treatment as a preventative measure, or treatment of water spaces with an approved treatment. In general, the most practical and cost-effective risk reduction measure is for vessels to discharge all bilge and retained seawater in the area where it was taken on-board, and to wash down all deck areas (with freshwater if possible), prior to departure for other areas. The use of chemical treatments may also be appropriate where approved by the relevant authorities. It would be impractical to regulate the discharge and/or treatment of bilge, but good management practice should be promoted through codes of practice (CoPs) where these exist.

Given the perception amongst some boat operators that bilge poses little or no biosecurity risk, and only limited evidence to prove otherwise, compliance with any bilge water measures might be low and non-compliance difficult to verify. To achieve a high uptake, therefore, measures to manage bilge would need to be simple and practical and be widely communicated. Research is needed to quantify the biosecurity risk from bilge water and to determine the efficacy of current treatment systems (e.g., oil-water separators, in-line filters) for mitigating risk.

Vessel biofouling

Biofouling risk can be mitigated through appropriate use and maintenance of anti-fouling coatings that are suited to a vessel's operational profile and by regular inspection and removal of biofouling in ship-yard facilities or by in-water cleaning. The limited capacity of ship-yard facilities in New Zealand and current legal restrictions mean that neither haul-out nor in-water cleaning is practical for most merchant shipping in the short-term. The proposed introduction of a *Craft Risk Management Standard* (CRMS) for international shipping, consistent with IMO guidelines for biofouling management, will encourage foreign-flagged commercial vessels to develop and maintain an auditable biofouling management plan (BMP) that details how biofouling is being managed. Similar requirements should be considered for domestic shipping.

Recent guidance recommends that in-water cleaning be allowed for vessels that have local biofouling at a level of fouling (LoF) <4 and biocide-free anti-fouling systems. Another option would be to allow in-water cleaning in designated areas with containment of biofouling waste. We recommend that MPI obtain legal advice on whether it would be necessary to amend the Marine Pollution Regulations to enable regional councils to authorise in-water cleaning in some circumstances, as recent court decisions have cast some doubt on this.

Movement controls should be considered for vessels with very high levels of fouling, particularly if they are seeking to visit high value areas. We recommend starting with movement restrictions on vessels with LoF >3 (i.e., greater than 15% of hull area fouled) and signalling an intention to move to controls on vessels with LoF >2 in the future. Commercial vessels with LoF >3 are most likely to have been inactive for some time and are being relocated to undertake specific projects (e.g., barges, dredges, etc.) or for cheaper berthage fees (e.g., derelict or decommissioned vessels). In these instances, movement controls or requirements for cleaning may be implemented through resource consents or as a condition of anchorage.

Dredging and dredged materials

Consents to undertake dredging programmes should require Assessments of the Environmental Effects (AEEs) to consider the biosecurity risks of the activity. Approved consents should include measures to mitigate the risk of spreading harmful organisms in biofouling and seawater carried by dredges and hopper barges, and in dredged material.

Mining and exploration pathway

The mining and exploration pathway includes activities involved in prospecting for and extracting petroleum (oil and gas) and minerals from within New Zealand's Territorial Sea, Exclusive Economic Zone and Extended Continental Shelf. Offshore exploration and production involves a range of vessel types and equipment that is used at different stages in the development life-cycle of a field. Harmful organisms can potentially be spread as biofouling attached to wetted surfaces of vessels, Mobile Offshore Drilling Units (MODUs) and production platforms, as biofouling attached to immersed equipment, through uptake in ballast water and seawater used for other ship-board operations (e.g., bilges, cooling water, etc.), through uptake in seawater used to slurry dredged material, as contaminants on maritime equipment (e.g., seismic streamers, side-scan sonar, magnetometers, ROVs, etc.), and as contaminants picked up unintentionally in material removed from the seabed (e.g., dredged material, corers, traps, ROVs, benthic sleds, etc.).

International best-practice in the offshore oil and gas industry is now to consider biosecurity risks at an early stage of project planning and to build mitigation strategies into the overall Environmental Management Plan (EMP) for the life-cycle of the project. This would include development of Standard Operating Procedures (SoP) for: (i) managing ballast water, bilge, biofouling and contaminants on vessels (see the measures described above for Merchant shipping) and equipment, (ii) for relocation of plant and equipment, and (iii) for decommissioning fields. Practical options for decontaminating plant and equipment include high pressure water-blasting, washing and air drying.

There are few feasible options within New Zealand to treat MODUs and large drill ships that arrive clean but become fouled after working for several weeks or months in one location. Any general policy should allow for users to comply through equivalent risk reduction measures, for example through MPI approval of a BMP that achieves an appropriate level of protection prior to movement. Such a plan could provide for inspection and assessment of fouling communities prior to movement within New Zealand.

Commercial Fishing

The commercial fishing pathway includes more than 1,500 registered commercial vessels in New Zealand that target inshore stocks of finfish, shellfish and seaweed, deep-water and middle-depth stocks of finfish and invertebrates, or highly migratory species such as tunas. Commercial fishing can potentially spread harmful marine organisms through uptake in ballast water and other seawater used for ship-board operations, in vessel biofouling or as biofouling attached to immersed equipment, as contaminants on fishing equipment (e.g., nets, chains, pots, etc.), through movement of livestock and bait (e.g., holding pens, bait wells, etc.), as contaminants picked up unintentionally from the seabed (e.g., benthic trawls), through deliberate movement of live catch of harmful organisms, as contaminants associated with the movement of live catch and associated equipment, and as waste discharged from processing facilities.

Biofouling risk can be mitigated through appropriate use and maintenance of anti-fouling coatings that are suited to the vessel's operational profile and by regular inspection and removal of biofouling in ship-yard facilities. Consideration should be given to development and maintenance of an auditable BMP for fishing vessels and to an industry Code of Practice that details SoPs for managing risks from bilge water, biofouling and contaminants on fishing equipment and for movement of livestock and bait. Practical options for decontaminating equipment include streaming of nets prior to relocation, water-blasting, washing and air drying. Industry training in the CoPs and independent audit will encourage greater uptake of best-practice within the sector.

Aquaculture

The aquaculture pathway includes activities involved in the capture, breeding, hatching, cultivating, rearing, and on-growing of marine organisms in coastal environments. Marine aquaculture can contribute to the spread of harmful marine organisms by providing artificial habitat on which populations develop, by transporting biofouling on vessels or mobile equipment (e.g., spat catching gear, buoys, ropes, anchors, mooring blocks, finfish cages, etc.), through uptake in seawater on vessels, as contaminants on marine equipment (e.g., anchors, chains, mooring ropes, etc.), through deliberate movement of spat/seed-stock or adult product, as contaminants associated with the movement of spat/seed-stock and associated equipment, and as waste discharged from processing facilities.

Internationally, measures introduced to reduce biosecurity risk within the aquaculture sector have involved the development of industry Codes of Practice (CoP) to complement official regulation of activities. These should cover the range of industry operations and can include procedures for appropriate harvesting and transfer of livestock, cleaning and disinfection of vessels, cages, and other farming equipment, treatment of diving equipment, managing biofouling on vessels and equipment, preventing escape of livestock, and managing waste from processing. Practical tools for each of these operations are discussed in Section 6.

Sterilisation of equipment might not be feasible for some marine farming activities (e.g., movement of large salmon cages and transfer of mussel spat on frames). Further consideration and consultation with industry is necessary to identify a workable approach. Improved record-keeping of stock and equipment transfers would improve the ability to manage outbreaks of harmful marine organisms and could also provide product traceability, which industry could promote in its marketing materials. Industry training in the CoPs and independent audit will encourage greater uptake of best-practice procedures for reducing risk.

A requirement for biosecurity certification of hatcheries and wild spat could be justified because of potential to spread harmful organisms quickly to multiple locations. The practical feasibility and cost would depend on the nature of the measures, which require further investigation.

Recreation and Sport

The recreation and sport pathway includes an estimated 600,000 private vessels, comprising trailered power and sailing boats, kayaks and canoes, jet-skis, motor launches and keeled boats. Harmful marine organisms can potentially be spread in seawater taken on board the vessels in bilges, catch or bait holding tanks, as contaminants entangled on the vessel or trailer or in biofouling growing on the submerged surfaces of vessels. Other, associated equipment, including anchors and chains, moorings, fishing gear, live bait, and diving equipment, can also transport marine species. Fixed structures, such as wharves, marinas, and jetties, can also play an important role in the spread of marine organisms by providing artificial substrata for the growth of harmful biofouling organisms that can then reproduce and infect moving vectors.

Trailered recreational vessels

Simple measures are available to reduce risks from trailered vessels, including inspection, cleaning and drying of the vessel, trailer and equipment after each journey or trip, removing attached biofouling or entangled organisms and rinsing and drying hull compartments. Uptake of these practices could be encouraged through greater availability of wash-down facilities, and targeted education/awareness campaigns.

Non-trailered recreational vessels

To manage risks from passive vessel biofouling on vessels (i.e., the discharge of larvae or viable organic material not caused by cleaning), five complementary measures could be implemented.

- Provide education and/or incentives for use and maintenance of anti-fouling coatings that are suited to the vessel’s activity.
- Encourage regular cleaning of vessels in approved shore-based facilities, particularly prior to movement from the region.
- Require vessel operators to follow an approved BMP (as recommended by the IMO).

- Require vessel operators to notify authorities in advance of intentions to visit specified high value areas, some of which could require approval and possibly an inspection.
- Impose movement controls on vessels that exceed a threshold LoF unless they can demonstrate compliance with an approved BMP.

Given that there is currently no registration or licensing requirement for non-commercial vessels there are significant agency costs in establishing and maintaining a vessel register and a record of approved BMPs, as well as monitoring compliance and taking enforcement action. The measure could also encounter substantial public opposition undermining the rate of uptake of such a measure.

Movement controls on boats with LoF ≥ 3 (i.e., macrofouling cover >5% of hull area), would be impractical in the short term, given that over 25% of moored vessels in this sector are likely to be in this category (see Section 7.1.2). We recommend starting with movement restrictions on very heavily fouled vessels (i.e., LoF ≥ 4 or greater than 15% of hull area fouled) and signalling an intention to move to controls on vessels with LoF ≥ 3 in the future. More stringent requirements could be implemented for vessels intending to travel to high value areas. Short-term closures of infested areas should also be considered during response to an incursion to reduce the rate of infestation of vessels and other mobile equipment. The spatial extent and duration of closure will be important influences on the feasibility of implementation.

Fixed and mobile structures

We recommend that local authorities require, as a condition of resource consents or permits (e.g., for moorings), that any new structures in the coastal environment be made using only new or sterilised materials. Existing structures or associated materials that have been in the marine environment should not be moved to another region, or substantial distances within a region, without first being sterilised (by encapsulation, heat treatment or removal from the water for cleaning). Alternatively, a risk assessment could be undertaken to determine the likelihood of translocating potentially harmful species. This could be promulgated through resource consents, where appropriate, and otherwise through CoPs and public awareness campaigns. Guidance on these matters could be provided in a national pathway management plan under the Biosecurity Act.

Research and Education

The research and education sectors include science providers, environmental consultancies, universities, polytechnics (including marine laboratories), and commercial aquaria that are involved in marine research or education. Activities undertaken by these organisation that can spread harmful marine organisms include the use of vessels (trailered and non-trailered) and scientific equipment in field surveys (e.g., diving gear, sampling equipment, and deployed instruments), deliberate movement of equipment or live organisms for experimentation, and the keeping and breeding of organisms in aquaria and hatcheries.

Although there are individual measures that can be taken to mitigate many of the risks involved in this sector (many of which are common to the other pathways described above), knowledge about them and their management is patchy within institutions and few have well-articulated, overarching policies for biosecurity that cover all of their operations. The sector should be encouraged to consolidate and improve on existing measures by developing auditable CoPs to manage biosecurity risks across their operations. These should include: a requirement for BMPs for all non-trailered vessels, wash-down/sterilisation protocols for trailered vessels and mobile equipment (including diving equipment), SoPs for field surveys and experimental studies that require assessment of the risks of spreading non-indigenous species (and propose mitigation strategies), and SoPs for managing risks from hatchery and aquarium facilities. Uptake could be encouraged by an awareness campaign at a high level within the organisations (e.g., General Managers of Operations) and by provision of template examples. Training in the CoPs and independent audit will encourage greater uptake of best-practice within the institutions.

Definitions and abbreviations

Anti-fouling system: a coating, paint, surface treatment, surface, or device that is used on a vessel or submerged equipment to control or prevent the attachment of organisms.

Ballast water: water, including its associated constituents (biological or otherwise), placed in a ship to increase the draft, change the trim or regulate stability. It includes associated sediments, whether within the water column or settled out in tanks, sea-chests, anchor lockers, plumbing, etc.

Bilge: any seawater that:

- accumulates within the hull of a vessel, including in the engine room of larger vessels (i.e., seawater that enters the vessel via the stern glands) and in the bilge sumps of smaller vessels,
- is contained in or on the vessel (e.g., for fish or bait), or
- is uncontained on the deck area of a vessel, including in gear storage areas.

Biofouling: the accumulation of aquatic organisms on surfaces immersed in, or exposed to, the aquatic environment.

BMP: Biofouling Management Plan and Record Book. A document that contains details of the anti-fouling systems and operational practices or treatments used to manage biofouling on a vessel. A BMP should contain a description of the vessel and its operating profile, including hull locations susceptible to biofouling, and a schedule of planned inspections, repairs, maintenance, and renewal of anti-fouling systems. The associated record book should detail all inspections and biofouling management measures undertaken on the ship.

BSA: Biosecurity Act 1993.

BWE: Ballast water exchange, a procedure in which the ballast water on a vessel is discharged and replaced by other water with the intention of reducing the risk of transferring harmful marine organisms to destination ports.

Clean of biofouling: having no visible aquatic organisms on the hull, including niche areas, except as a slime layer.

CoP: Code of practice.

Biological contaminant: a living organism that is unintentionally carried within or on transported equipment, goods, living stock or other materials. For the purposes of this study, this does not include pathogens or parasites.

Controlled area: an area for the time being declared, under section 131 of the Biosecurity Act 1993, to be an area that is controlled to:

- enable the limitation of the spread of any pest or unwanted organism, or
- minimise the damage caused by any pest or unwanted organism, or
- protect any area from the incursion of pests or unwanted organisms, or
- facilitate the access of New Zealand products to overseas markets, or
- monitor risks associated with the movement of organisms from parts of New Zealand the pest status of which is unknown.

Craft: an aircraft, ship, boat, or other machine or vessel used or able to be used for the transport of people or goods, or both, by air or sea; and includes:

- an oil rig and,

- a structure or installation that is being towed through the sea.

Craft Risk Management Plan: a plan approved under section 24K of the Biosecurity Act 1993.

Craft Risk Management Standard: a standard issued under section 24Gof the Biosecurity Act 1993.

Dead Weight Tonnage (DWT): a measure of the maximum amount of weight that a ship can safely carry. It is the sum of the weights of cargo, fuel, freshwater, ballast water, provisions, passengers, and crew.

Exclusive Economic Zone (EEZ): The EEZ of New Zealand comprises those areas of the sea, seabed, and subsoil that are beyond and adjacent to the Territorial Sea of New Zealand, having as their outer limits a line measured seaward from the baseline described in sections 5 and 6 and 6A (of the Territorial Sea, Contiguous Zone, and Exclusive Economic Zone Act 1977), every point of which line is distant 200 nautical miles from the nearest point of the baseline.

Extended Continental Shelf (ECS): the seabed and subsoil of New Zealand's submerged landmass where it extends beyond the EEZ.

Gross Tonnage (GT): a measure of a ship's overall internal volume.

Harmful marine organisms: any marine organism, indigenous or non-indigenous, that has the potential to cause harm to valued marine species, ecosystems or environments. For this report, pathogens and other disease-causing agents are excluded from this definition as measures to manage these risks are outside the scope of the project.

HSNO Act: Hazardous Substances and New Organisms Act 1996.

International Maritime Organisation (IMO): the United Nations specialized agency with responsibility for developing and maintaining a comprehensive regulatory framework for international shipping.

Internal waters: harbours, estuaries, and other areas of the sea that are on the landward side of the baseline of the Territorial Sea of a coastal state, and rivers and other inland waters that are navigable by ships.

LoF – Level of fouling. A 6-point scale developed by Floerl et al. (2005) to describe the intensity of biofouling based on visual observations of the percentage cover of biofouling on the surface and range of different taxa of marine invertebrates and plants that are present.

Marine growth prevention systems (MGPS): an anti-fouling system used for the prevention of biofouling accumulation in internal seawater cooling systems and sea-chests and can include the use of anodes, injection systems and electrolysis.

MARPOL: the International Convention for the Prevention of Pollution from Ships 1973/78 is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes.

Merchant vessel: a vessel that has the primary role of the transport of cargo. Merchant vessels can be divided into different categories depending on their purpose and/or cargo (e.g., bulk carrier, tanker, container, refrigerated vessel, etc.).

MPI: Ministry for Primary Industries.

New Organism:

- an organism belonging to a species that was not present in New Zealand immediately before 29 July 1998,
- an organism belonging to a species, subspecies, infrasubspecies, variety, strain, or cultivar prescribed as a risk species, where that organism was not present in New Zealand at the time of promulgation of the relevant regulation,

- an organism for which a containment approval has been given under the HSNO Act,
  - i) an organism for which a conditional release approval has been given,
  - ii) qualifying organism approved for release with controls,
- a genetically modified organism, or,
- an organism that belongs to a species, subspecies, infrasubspecies, variety, strain, or cultivar that has been eradicated from New Zealand.

Niche areas: areas on a ship that are susceptible to biofouling due to, different hydrodynamic forces, susceptibility to coating system wear or damage, or being inadequately, or not, painted. They include, but are not limited to, the wind/waterline, sea-chests, bow thrusters, propeller shafts, inlet gratings, jack-up legs, moon pools, bollards, braces and dry-docking support strips.

New Zealand waters: the internal waters of New Zealand and the territorial sea of New Zealand.

Passenger vessel: a vessel that has the primary role of carrying passengers. A cruise liner is a type of passenger vessel that is used for pleasure voyages, where the voyage and the ship's amenities form part of the experience.

Pathway: movement that

- is of goods or craft out of, into, or through
  - a particular place in New Zealand, or,
  - a particular kind of place in New Zealand, and
- has the potential to spread harmful organisms.

Pathway Management Plan: a plan to which the following apply.

- It is for the prevention or management of the spread of harmful organisms.
- It is made under Part 5 of the Biosecurity Act 1993.
- It is a national pathway management plan or a regional pathway management plan.

Recreational vessel: a vessel that has the primary role of recreation (that is, not intended for commercial use or hire, regardless of length or tonnage).

RMA: Resource Management Act 1991*.*

Sedimentary basin: a major geographical region with a common geological history and continuous stratigraphy. New Zealand sedimentary basins can be subdivided into "Petroleum Basins", and "Frontier Basins”. All or part of each "Petroleum Basin" has been licensed for exploration. Within a basin are expected to be, a number of petroleum fields. Maui, Kapuni, Pohokura and Kupe are all examples of fields in the Taranaki basin.

Slime layer: a layer of microscopic organisms, such as bacteria and diatoms, and the slimy substances that they produce.

Small-scale management programme: a small-scale management programme declared by a regional council consisting of:

- small-scale measures to eradicate or control an unwanted organism, and
- provisions for compensation for losses caused by the programme.

SoP: Standard operating procedures.

Structure: (as defined in the RMA) “any building, equipment, device, or other facility made by people and which is fixed to land; and includes any raft.” In this report, we also refer to “moveable structures” meaning structures that are generally fixed to land (including the seabed) but can be shifted to another location.

Territorial sea: comprises those areas of the sea having, as their inner limits, a baseline described in sections 5 and 6 and 6A (of the Territorial Sea, Contiguous Zone, and Exclusive Economic Zone Act 1977) and, as their outer limits, a line measured seaward from that baseline, every point of which line is distant 12 nautical miles from the nearest point of the baseline.

Vector: the physical means by which harmful organisms may be transported.

Vessel: a mobile structure of any type whatsoever operating in the marine environment and includes floating craft, fixed or floating platforms, and floating production storage and off-loading units (FPSOs).

1 Introduction

There are more than 170 non-indigenous (exotic) species known from New Zealand's coastal environments, including some that are considered harmful (Kospartov et al. 2008). Once they are present in our waters, harmful marine organisms[1] can be spread throughout the country by a variety of means ('pathways'). The impacts that these species have on New Zealand's marine environments and resources can be minimised by restricting their distribution and/or by reducing the rate at which they are spread.

To reduce the risk of harmful marine organisms entering New Zealand coastal waters, the Government has introduced mandatory controls on the discharge of ballast water from ships entering New Zealand and is working toward the introduction of a Craft Risk Management Standard (CRMS) for biofouling on international vessels. To reduce the spread of harmful marine organisms within New Zealand, the Ministry for Primary Industries (MPI) is exploring the potential to develop national and regional pathway management plans, in collaboration with regional councils, industry and other stakeholders.

MPI commissioned the National Institute of Water and Atmospheric Research (NIWA) and the Cawthron Institute (Cawthron) to undertake a review of practical measures and policy options for reducing the spread of potentially harmful marine organisms via human transport pathways within New Zealand. A companion report (Sinner et al. 2013) (hereafter referred to as the "Part B report") describes the statutory framework for management, assesses policy options for implementing risk reduction measures and makes recommendations regarding options that are most likely to be practical and effective. This report describes the nature of each pathway and the practical options available to reduce risk.

1.1 Pathways, vectors and risks

The Biosecurity Act 1993 (BSA) defines a "pathway" as movement that

- is of goods or craft out of, into, or through:
  - a particular place in New Zealand or,
  - a particular kind of place in New Zealand and,
- has the potential to spread harmful organisms.

Pathways are human activities that, intentionally or unintentionally, may move a harmful organism from one place in New Zealand to another.

This review focuses on six pathways that may spread harmful marine organisms within New Zealand.

- Maritime transport.
- Mining and exploration.
- Commercial fishing.
- Marine aquaculture.
- Sport and recreation.
- Research and education.

[1] For purposes of this report, "harmful marine organism" is defined as any marine organism, indigenous or non-indigenous, and including any pathogen or disease, that has the potential to cause harm to valued marine species, ecosystems or environments.

Within each of these pathways marine organisms can be transported in a variety of ways ('vectors'). The most studied vectors for the transport of harmful marine organisms are movement of vessels (of all sizes) and immersed moveable structures (Biodiverse Limited 2010). Ballast water and hull biofouling are widely regarded as key mechanisms of transport of harmful organisms by these vectors (Hewitt et al. 2004, Inglis et al. 2010).

There are, however, a number of other vectors and transport mechanisms for harmful marine organisms where the risk is less well understood (Carlton 2001, Elston 1997, Hayes et al. 2005, Ruiz & Carlton 2003). These include:

- **bilge water** (Darbyson et al. 2009a),
- **overland movements of small craft.** For example, trailered boats and kayaks (Dodgshun et al. 2007, Sinner et al. 2009),
- **contamination of equipment associated with marine activities**. Examples are entrained water on dive gear, entrained sediments on anchors; and fouling or entanglement in equipment such as nets, lobster pots, ropes, floats, and ground tackle (Acosta & Forrest 2009, Dodgshun et al. 2007, Sant et al. 1996), and
- **movement of bait and live organisms for marine aquaria, research or education.** For example, the unwanted seaweed *Caulerpa taxifolia* is an aquarium species.

Because harmful marine organisms may be spread by humans through diverse means, there is unlikely to be a single best approach to risk mitigation. All pathways must be addressed to achieve the desired outcome of reducing the rate of spread. The best outcome is likely to be achieved through a variety of mechanisms that are tailored to address specific risks within each pathway.

This report summarises the transport vectors, the ways in which harmful marine organisms may be spread within each pathway and the practical tools available for managing risks within them.

2 Methodology and considerations for pathway management

The project team reviewed published and unpublished information on risks associated with each of the marine pathways and options for their management. To engage with industry, government, tangata whenua, councils, and other stakeholders, two workshops were held in Wellington (4-5 March and 24 April 2013) to identify and discuss risk reduction options and potential barriers to their implementation. Inputs from the literature review and workshops were then used in the development of a recommended package of measures and policies for reducing the domestic spread of harmful marine organisms within New Zealand. Attendance at the workshop included representatives from the following sectors.

- Commercial fishing,
- Government,
- Iwi,
- Marine aquaculture
- Maritime transport and,
- Scientific research.

2.1 Considerations for pathway management

From the first workshop, five considerations were identified that, while not intended to cover all aspects of pathways management, could underpin evaluation and selection of measures to reduce risk in the pathways.

1. Where practical, domestic biosecurity measures should be aligned with measures being implemented at the border and internationally to simplify compliance and reduce complexity and cost. Measures should also be aligned between regions and across sectors, as they are more likely to be effective if applied consistently, while allowing for appropriate variation in detail.
2. Risk reduction measures should be applied wherever practicable and cost-effective. The goal is to reduce risk across all pathways, not necessarily achieve equivalence in the residual risk across sectors. However, the effort (and cost) required to reduce risk should not be significantly out of proportion to the relative risk from a given pathway.
3. Implementation should be aligned with changes to regional coastal plans and other instruments (e.g., codes of practice) to ensure consistency and facilitate uptake.
4. Effective risk reduction requires high levels of compliance with proposed measures, since even small numbers of non-compliant vectors can substantially reduce effectiveness. There is a role for both voluntary and regulatory measures. Compliance with voluntary measures needs to be monitored and evaluated and regulatory measures should include consequences for non-compliance.
5. This project aims primarily at inter-regional scale, but should also inform measures for management at local scales (either on an on-going basis or to inform incursion response). Pathway management should aim to reduce the risk

of spread at scales greater the rate of natural spread within, for example, a 5-year time frame.

2.2 Criteria for assessing management options

The options identified in the literature review and Workshop 1 were assessed using the following criteria, which are based on earlier marine biosecurity work for MPI (Inglis et al. 2012).

Effectiveness – the degree to which biosecurity risk would be reduced if the measure is appropriately applied in all relevant circumstances (i.e., the *technical efficacy* based on biology and ecology).

Practical Feasibility – the degree to which practical considerations, including feasibility of monitoring and enforcement, are conducive to adoption by stakeholders.

Cost of compliance – the financial and non-financial costs to stakeholders of complying with the measure, plus the costs to central and local government of promoting, monitoring and enforcing compliance.

Rate of uptake – taking into consideration cost and feasibility, the likely proportion of stakeholders who would adopt the measure and apply it appropriately.

Other considerations – other factors to consider, including alignment with principles for this project and wider government policies and strategies.

Collectively, these criteria suggest a wider **benefit-cost criterion**, where benefit:cost (B:C) is defined as follows:

B:C = [effectiveness*rate of uptake] / [cost of compliance]

where rate of uptake = *f*(practical feasibility, cost of compliance, other considerations).

That is, the likely benefits (i.e., risk reduction) from a measure are a function of the measure's effectiveness and rate of uptake, and can be compared to the cost of compliance for marine users and government agencies. For example, if a measure has a technical effectiveness of 80% but only 50% of marine users were likely to implement it, the risk reduction in practice would be only 40%. Furthermore, the likely rate of uptake of a measure by marine users will be influenced by its practical feasibility and cost of compliance, and possibly other considerations.

The overall assessment of options is then a consideration of likely risk reduction relative to the costs, taking into account other relevant factors. Information to assess options against these criteria was obtained during the literature review and the workshops and complemented by the authors' own experiences. This project did not extend to developing quantitative estimates of these criteria, however, so the benefit-cost criterion has been applied only implicitly.

It is worth noting that, in management of harmful marine organisms, high levels of uptake of new practices, across a range of stakeholders, may be required to ensure a programme's success (Polonsky et al. 2004). Behavioural change requires not just knowledge of the problem and potential solutions, but the ability to overcome relevant constraints. These might include cost, technological barriers and social pressure (Kollmuss & Agyeman 2002). The ability of individuals to change their behaviour can be unevenly distributed, so change can be patchy even when there is a willingness to change (Blake 1999, Reaser 2001).

3 Maritime transport pathway

The maritime transport pathway includes the movement of cargo and people by commercial shipping within New Zealand. This pathway also includes domestic movement of passenger vessels, slow-moving barges and dredges and other non-trading commercial vessels (e.g., tugs, tenders, pilot vessels, cargo barges, marine safety vessels, ferries, etc.).

3.1 Merchant and passenger vessels

New Zealand has 16 commercial seaports, 12 of which handle international trade (Rockpoint Corporate Finance Ltd 2009). About 15% of New Zealand's inter-regional domestic freight is transported by sea (Ministry of Transport 2008).

Commercial shipping within New Zealand includes both domestic (New Zealand registered) and international (foreign registered) ships. New Zealand has a small domestic commercial fleet with only 15 registered vessels >45 m length. These include 3 specialist bulk carriers, 5 Cook Strait ferries, 3 general cargo vessels, and 2 coastal freighters (Rockpoint Corporate Finance Ltd 2009).

Foreign registered vessels carry most of New Zealand's domestic maritime freight. About 800 individual vessels visit New Zealand each year, many making multiple scheduled trips (Maritime New Zealand 2011a). In 2009, New Zealand was served by around 41 international services provided by 22 shipping lines (Rockpoint Corporate Finance Ltd 2009). They accounted for about 6,000 of the ~7,000 port-to-port movements within New Zealand each year by large vessels (>99 GT) and carried ~79% of coastal container volumes (Hayden et al. 2009, Ministry of Transport 2008). Most domestic movements are by container vessels (35.9%), general cargo ships (23.6%) and bulk carriers (16.7%), with vehicle/passenger/livestock vessels and tankers comprising a further 8.8% and 8.3%, respectively (Hayden et al. 2009).

A large proportion of domestic port-to-port movements by foreign vessels are of relatively short distance (Table 3-1). For example, around 30% of the average weekly movements within New Zealand are between the Ports of Auckland, Tauranga and Napier. Table 3-1 also shows the importance of key hub ports, such as Auckland, Tauranga, Napier and Lyttelton, which are the source of ~⅔ of the average weekly movements. The trend by international shipping companies to move to 'hub and spoke' service networks is expected to increase demand for inter-regional freight movement within New Zealand over the coming years (Ministry of Transport 2008, Rockpoint Corporate Finance Ltd 2009).

New Zealand domestic ships include 2 bulk tankers that transport oil products from Marsden Point to facilities in Auckland, Tauranga, Napier, Wellington, New Plymouth, Nelson, Lyttelton, Timaru, Otago and Bluff and three dry bulk carriers that transport cement from processing facilities in Whangarei and Westport to other New Zealand ports. The 2 domestic cargo lines operate weekly services that link: (1) Lyttelton, Nelson, Taranaki and Onehunga, (2) Lyttelton, Dunedin, Tauranga and Auckland, (3) Wellington and Nelson and (4) Wellington and Lyttelton. Smaller, dedicated services carry cargo to the Chatham Islands (predominantly from Napier and Timaru) and nearshore islands in the Hauraki Gulf and elsewhere.

New Zealand domestic vessel services also include regular inter-island crossings for passengers and freight, which account for ~7,000 sailings between Wellington and Picton each year (Rockpoint Corporate Finance Ltd 2009).

Table 3-1. Average percentage of weekly domestic port-to-port connections made by international vessels. Data are for the 2008-09 year. (Source: Rockpoint Corporate Finance Ltd 2009).

From \\ To	MAP	ONE	AKL	TRG	NPE	NPL	WLG	MLB	NSN	LYT	TIU	POE	BLU	Total
MAP			1.0	1.3										**2.3**
ONE														**0.0**
AKL	1.3			6.5	2.6	2.1	1.3			4.7		2.6		**21.1**
TRG	1.3		6.3		0.8	2.6			1.3	1.3				**13.6**
NPE			0.8	11.7					2.1			2.6		**17.2**
NPL							1.3			3.4				**4.7**
WLG					5.2				2.1					**7.3**
MLB														**0.0**
NSN			1.6	1.8	2.1					0.8				**6.3**
LYT			1.3		5.7		7.3		1.3					**15.7**
TIU												2.6		**2.6**
POE					2.6					3.9				**6.5**
BLU												2.6		**2.6**
Table Totals	**2.6**	**0.0**	**11.0**	**21.4**	**19.1**	**4.7**	**9.9**	**0.0**	**6.8**	**14.1**	**0.0**	**10.4**		**100.0**

MAP = Marsden Point, ONE = Onehunga, AKL = Auckland, TRG = Tauranga, NPE = Napier, WLG =Wellington, NPL = New Plymouth, MLB = Marlborough, NSN = Nelson, LYT = Lyttelton, TIU = Timaru, POE = Otago, BLU = Bluff

International cruise ships currently make about 500 port calls per year (Maritime New Zealand 2011a). These tend to be to the main cruise ports of Auckland, Tauranga, Napier, Wellington, Lyttelton, and Port Chalmers (Dunedin), but may also include a visit to Fiordland National Park, all within a 7-day period. The most common ports of arrival are Auckland, Dunedin and Milford Sound (Tourism New Zealand 2007). Slightly longer voyages include visits to other regions such as Bay of Islands, Picton, Akaroa, Stewart Island, or Gisborne (Cruise New Zealand 2010, Inglis et al. 2012). Smaller, ‘expedition’ cruises spend more time in areas of New Zealand that large ships are unable to access, such as the Kermadec Islands, New Zealand's sub-Antarctic islands and Antarctic territories, as well as the smaller inlets and coves around Fiordland National Park and Marlborough Sounds.

Port visits by international cargo and passenger vessels are typically of relatively short duration (1-3 days; Inglis et al. 2012). Characteristics of these vessels and their operations have recently been described by Inglis et al. (2012). Commercial shipping lines are generally on very tight schedules and have very limited contingency for delays. Delays incur costs to the shipping line through unproductive vessel time and the need to reschedule forward itineraries. Because of this, contracts between shipping lines and independent terminal operators generally contain specifications on the required minimum quayside productivity for loading and unloading of cargo (Notteboom 2006). Ports are under strong commercial pressure to increase the efficiency of cargo handling and thereby reduce the time that cargo vessels are in port.

The duration of port visits by passenger vessels is also dictated by their forward schedules and the need for the voyage to integrate with the airline connections of passengers who have booked an “air/sea” package. Time delays can also be very expensive (Inglis et al. 2012).

3.2 Dredges & barges

Port-to-port movements of barges and dredges are usually in response to the needs of individual projects. Port companies typically hold resource consents to carry out maintenance dredging operations to maintain the depth of channels, turning basins and berthage areas. The frequency of maintenance dredging varies among ports, but is, in many cases, part of the port's annual operations.

Capital dredging occurs less frequently, involves larger works to reconfigure or deepen channels and port basins for port expansion or changes in operations, and will often involve use of bigger dredges. The ports of Tauranga, Lyttelton and Otago are all currently seeking resource consent for capital dredging works to enable access of larger, Post-Panamax class container vessels. Capital and maintenance dredge programmes are also carried out by boat marinas as required.

Different types and sizes of dredge may be used for different types of operations. Mechanical dredges (bucket, clam shell and backhoe dredges) scoop sediment from the seafloor and transfer it to a vessel or barge for transport to a spoil site. Suction dredges (e.g., trailing, cutter and auger head dredges) are fitted with cutting or hydraulic devices that break up and loosen sediment and soft rock. The loosened material is then sucked up with water into storage compartments ('hopper') on the dredge or an accompanying barge, where dewatering occurs. In some cases spoil is pumped directly to reclamation sites. Dredging ploughs (a towed blade) may also be used to level humps and hollows on the sea bed after maintenance dredging has been completed.

In general, maintenance dredging within New Zealand ports is undertaken by small mechanical or Trailing Suction Hopper Dredges (TSHDs) that are domiciled within New Zealand. Two small TSHDs are based in New Zealand and chartered for maintenance dredging works within New Zealand and Australia. The *New Era* (hopper capacity 600 m^3) is owned and operated by the Port of Otago and is based in Dunedin and the *Pelican* (hopper capacity 966 m^3), owned by international dredge company Van Oord NV, is based in Timaru (Pullar & Hughes 2009). A number of marine services contractors also own and operate smaller cutter suction, backhoe, clamshell and bucket dredges, hopper barges and tugs that are used in maintenance dredging and marine construction works within New Zealand. The type of dredge utilised depends on the activity (e.g., channel deepening, turning basin excavation, pipe laying, etc.), the amount of material to be removed and the operational costs.

Because capital dredging works typically involve removal of much larger quantities of material from the seabed (millions of m^3 compared with 10's of thousands of m^3 for maintenance dredging), significantly larger dredges with much larger hopper capacity are usually needed. These are typically contracted from outside New Zealand (Lyttelton Port Company 2012, Pullar & Hughes 2009).

Motorised and towed barges may also be used to transport cargo and machinery among ports and to offshore islands, where there are not regular freight services. They are also used to support maritime and coastal construction activities.

3.3 Other non-trading vessels

A range of other commercial, non-cargo vessels also operate in New Zealand's waters. These include: service vessels, such as tugs, pilot boats, local ferries and water taxis; patrol vessels; offshore support vessels; cable laying ships, etc. These non-trading vessels often work locally, within the region they are domiciled, but may make longer distance voyages to other New Zealand locations.

3.4 Modes of infection

Modern maritime vessels can transport potentially harmful marine organisms in a number of ways (Carlton 2001, Hewitt & Campbell 1999, Hewitt & Campbell 2010):

- through uptake in **ballast water** used to control the stability of the vessel,
- **as biofouling** attached to wetted surfaces of the hull or 'niche' areas (e.g., dry-dock support strips, sea-chests, propeller, rudder, exposed surfaces of water piping, thruster tunnels, etc.),
- through uptake in seawater used for other **ship-board operations** (e.g., bilges, cooling water, holding tanks, etc.),
- as **contaminants** picked up unintentionally during deployment and retrieval of maritime equipment (e.g., anchors, chains, mooring ropes, etc.), and
- as **contaminants** picked up unintentionally in material removed from the seabed (e.g., dredge spoil).

3.4.1 Ballast water

Ballast water is carried mainly by merchant vessels, some cruise ships and certain types of ferries. A merchant vessel arriving in a port unladen will usually be ballasted and need to discharge its ballast water in proportion to the weight increase during cargo loading. Both domestic and foreign ships may load and unload cargo in New Zealand ports. During loading and unloading of cargo the vessels may discharge or recharge their ballast tanks with water from within New Zealand territorial waters, potentially transferring water from one port to another. Light and medium ballasted vessels account for most port arrivals (respectively 38.9% and 36.6%), followed by heavily ballasted vessels (21.3%) (Hayden et al. 2009).

Discharge of ballast water is widely recognised as an important mechanism for the spread of harmful marine organisms between countries and regions (Briski et al. 2012, Carlton 2001, Lavoie et al. 1999, MAF Biosecurity New Zealand 2007b). Ballast water can potentially carry a range of species in adult and/or juvenile forms. However, it is most likely to transport the planktonic life-stages (e.g., larvae, spores, fragments) of marine organisms.

The risks associated with ballast water are influenced by the volume of ballast transported and discharged by a vessel, the number of vessels on the pathway discharging ballast, the number of potentially harmful species present at the site of uptake, season, transit time, and the environmental similarity of the source and receiving environments (Barry et al. 2008, Briski et al. 2012, David et al. 2007, Gollasch et al. 2000). In general, dry and liquid bulk carriers transport and discharge the greatest volumes of ballast per vessel during loading operations.

3.4.2 Bilge water and anchor lockers

Marine species can also be transported in damp or fluid filled spaces like anchor lockers and bilge water. Bilge water is any water retained on a vessel (other than ballast) that is not deliberately pumped on-board, but which accumulates within the hull of a vessel, including in the engine room of larger vessels (i.e., seawater that enters the vessel via the stern glands) and in the bilge sumps of smaller vessels, seawater contained in or on the vessel (e.g., for fish or bait), and uncontained water on the desk area of a vessel, including in gear storage areas. Bilge water can, therefore, comprise a mixture of water, detergents and other chemicals, fuel oil and other hydrocarbons, soot and dirt.

Compared to ballast water, the volumes of bilge water on board a vessel are very small. Nonetheless, bilge water does contain biosecurity risks. A recent Canadian study, for example, suggested that bilge water could be an important regional-scale mechanism for the spread of harmful marine organisms. Darbyson et al. (2009a) collected samples of bilge water from 35 recreational and commercial fishing vessels domiciled in eastern Canada. Thirty-one taxa were identified from the bilge water; about ⅔ of the number of taxa recorded from scrapings of biofouling taken from the vessels at the same time. A range of planktonic organisms was recorded, including crab larvae.

Anchor lockers and other damp spaces where equipment is stored may contain marine species that are brought aboard during recovery of the anchor or equipment. The invasive aquarium weed, *Caulerpa taxifolia*, is known to be spread in this way (Sant et al. 1996).

3.4.3 Biofouling

Biofouling is the growth and accumulation of marine organisms on surfaces that are immersed in, or exposed to, marine environments. It includes marine organisms that attach to or live on any parts of a vessel (or other structure) including its hull and 'niche' areas (areas that are recessed or protected from water drag or which are not adequately protected by an anti-fouling coating) and internal seawater systems (Bell et al. 2011). Biofouling can lead to the spread of harmful marine organisms either through passive (unintentional) discharge of reproductive or other viable organic material or through the intentional removal of biofouling during in-water cleaning of the hull when viable organisms may be dislodged and survive.

Management of biofouling growth is an important part of the operations of most modern merchant vessels. As biofouling accumulates it imposes a penalty on fuel consumption and engine wear so that the vessel is less able to maintain speed and meet tight schedules (AMOG Consulting 2002). For this reason, the hulls of merchant vessels are regularly painted with special coatings ('anti-fouling coatings') that are designed to prevent the build-up of biofouling (AMOG Consulting 2002, Dafforn et al. 2011, Floerl et al. 2010). A large range of anti-fouling coatings is used by maritime shipping. Some incorporate toxic compounds (biocides) that are released from the paint over time, while others rely on their physical nature (e.g., foul release coatings) or regular cleaning (e.g., mechanically resistant coatings) to prevent biofouling (Dafforn et al. 2011, MAF Biosecurity New Zealand 2011). These practices and vessel speed mean most modern cargo and passenger vessels have relatively low levels of biofouling on the general hull surface (Coutts & Taylor 2004, Inglis et al. 2010). The most heavily fouled areas of the hull tend to be niche areas such as, sea-chests, dry-dock support strips, bow thrusters and tunnels, rudders, anodes, and bilge keels.

Biofouling will accumulate on the vessel as the anti-fouling coating ages, during extended periods of inactivity (i.e., lay-up) and where the coatings have been damaged or inappropriately applied (Inglis et al. 2010, MAF Biosecurity New Zealand 2011). For these reasons there can be large variation among vessels in the amount of biofouling present during their operational period. In large vessels, recessed areas like sea-chests or water intakes may not be painted with anti-fouling coatings or be maintained as regularly as the external hull surfaces. It is in these spaces that large growths of biofouling and adult life-stages of mobile species can live (Coutts & Dodgshun 2007, Coutts et al. 2003).

Because of the costs involved in dry-docking large vessels (see Section 3.10), owners of merchant and passenger vessels usually schedule hull cleaning and reapplication of anti-fouling coatings at the time that certification surveys are required by the vessel's classification society(s) or when urgent repairs are needed (Takata et al. 2006). Foreign-registered merchant vessels that operate in New Zealand and New Zealand-registered vessels that are ≥500 GT and operate internationally are subject to the requirements of the International Convention for the Safety of Life at Sea, 1974, (SOLAS). SOLAS ships that are not passenger vessels are required to undertake a renewal survey for certification at least every 5 years (Maritime New Zealand 2011d). This requires an out-of-water inspection of the ship's hull. There must also be a minimum of two surveys of the outside of the hull during any five year period. These between survey inspections may be undertaken in-water (Maritime

New Zealand 2011d). SOLAS passenger vessels typically enter dry-dock every 2 - 3 years to satisfy certification requirements (Knapp & Franses 2006, Lyons 2007).

Domestic commercial vessels >45 m in length that are not SOLAS ships, vessels <45 m in length, and fishing vessels are required to comply with the Safe Ship Management (SSM) requirements of the Maritime Transport Act 1994 (Maritime Rule Part 21; Maritime New Zealand 2011c). Maritime Rule 46.17 requires vessels under an approved SSM system to undergo an out-of-water inspection of the hull and external fittings every two years (Maritime New Zealand 2011d). The period between these inspections may be extended for ships ≥24 m in length that have steel or aluminium alloy hulls. Granting an extension is at the discretion of the organisation managing the SSM and will need to ensure that at least two such inspections are carried out in any 5 year period with no more than 3 years between any two inspections (Maritime New Zealand 2011d).

Many non-trading vessels, such as barges and dredges, operate at slower speeds than merchant cargo or passenger vessels so hydrodynamic drag plays less of a role in restricting the growth of biofouling on the hull. Non-trading vessels can also spend long periods of time inactive within port environments. For these reasons, non-trading vessels will often carry much greater biomass and diversity of biofouling organisms than trading vessels. At a pathway-scale, it is difficult to determine which group of vessels constitutes the greater overall biosecurity risk: the relatively small number of non-trading vessels that travel infrequently between regions, but which have a greater per vessel biomass of biofouling, or the larger number of movements by trading vessels that carry fewer organisms and individuals. Recent theoretical and experimental studies suggest that frequent transport of small numbers of individuals may present the greater risk (Hedge et al. 2012), but there are few empirical data at the appropriate pathway scale to demonstrate this conclusively (Wonham et al. 2013).

There is less commercial imperative for non-trading vessels such as barges, dredges, ferries, and harbour pilot vessels to maintain a hull free of biofouling. Nevertheless, as commercial vessels, all will have survey requirements to ensure the structural integrity of the hull. Under Maritime Rule 46.23, the owner of a barge must ensure that an inspection is done of the barge's bottom before it is put into service and then at intervals not exceeding 5 years (Maritime New Zealand 2011d).

3.4.4 Dredge spoil and washings

Relocation of dredge material is a potential vector for harmful marine organisms. For most species it is not known to what extent they can survive the dredging process or disposal site environments (Australian Government 2009). Although the risks of translocation in dredged material have received relatively little study, there is potential for transport of sediment dwelling organisms, particularly those with resistant benthic stages (e.g., cysts or spores). Preliminary research indicates that the amount of unwanted sediment that trailer suction hopper dredgers transport between locations is likely to be greater than the quantities carried in ballast tanks and that the range of species carried is likely to be different (Australian Government 2009). There is also the potential for harmful organisms or their offspring to be transported within water taken into the dredge and hoppers or barges and on anchors and other ancillary equipment.

3.5 Available practices to reduce risk – ballast water

3.5.1 International Measures

The International Maritime Organisation (IMO) adopted the *International Convention for the Control and Management of Ships' Ballast Water and Sediments* (the Ballast Water Management Convention; BWMC) in 2004. The BWMC was introduced to provide a platform for consistent national regulation of ballast water for minimizing the transfer of harmful aquatic organisms and pathogens. When it enters into force it will apply to ballasted vessels that move between the coastal waters of different countries or port states[2]. It will not apply to New Zealand flagged ships that operate only in New Zealand waters (MAF Biosecurity New Zealand 2007b).

The BWMC incorporates two main approaches to manage risks from ballast water.

- A ballast water exchange (BWE) standard (Regulation D-1).
- Treatment of ballast water to meet specified performance standards (Regulation D-2).

The BWE standard specifies that exchange of coastal waters should be undertaken at least 200 nm from the nearest land and in water depths of at least 200 m. If this is not possible, then BWE should be undertaken as far from the nearest land as possible, and in all cases at least 50 nm from the nearest land and in water at least 200 min depth. In sea areas where these conditions cannot be met, the port state may designate a BWE area, in consultation with adjacent or other states, as appropriate.

A general principle of the BWMC is that, as far as possible, a ship should not be required to deviate from its intended voyage and the voyage should not be delayed. However, a port state may require a ship to deviate, which may result in a delay, where a designated BWE area has been established. Ships should also never be asked to comply with any requirements that might lead to endangerment of the safety or stability of the ship, its crew, or its passengers because of adverse weather, ship design or stress, equipment failure, or any other extraordinary condition (David & Gollasch 2008).

The BWE standard is generally seen as an interim measure until permanent on-board ballast water treatment systems can be adopted by vessels. Pending the BWMC coming into force, new ships will progressively be required to meet new ballast water discharge standards (Regulation D-2) from the Convention that will require on-board treatment of ballast water for all ships travelling between countries. From 2016 onwards, existing vessels will be required to meet the discharge standard. Regulation D-2 specifies that discharged ballast must be treated so that it contains:

- <10 viable organisms $\geq$50 µm in minimum dimension per m^3, and
- <10 viable organisms per ml <50 µm in minimum dimension and $\geq$10 µm in minimum dimension, and
- less than the following concentrations of indicator microbes, as a human health standard:
  - Toxigenic *Vibrio cholerae* (serotypes O1 and O139) with <1 colony forming unit (cfu) per 100 ml or <1 cfu per 1 g (wet weight) of zooplankton samples,
  - *Escherichia coli* <250 cfu per 100 ml, and
  - Intestinal *Enterococci* <100 cfu per 100 ml.

All ships are required to implement a Ballast Water and Sediments Management Plan and to carry a Ballast Water Record Book that details how ballast water has been managed on-board.

Under the BW Convention, treatment systems for ballast water must be approved by the IMO (Regulation D-3). This approval is contingent upon ship-board testing of the system to ensure

[2] This will occur when at least 30 States, representing 35% of the world merchant shipping tonnage ratify it. Thirty-six states have so far acceded to the BW Convention, representing 29% of the world merchant shipping tonnage (International Maritime Organization 2013b).

it meets the Regulation D-2 performance standard. By March 2013, 28 BWMSs had received a Final Approval from the IMO and 29 have received a Type Approval certificate issued by an administration that confirms compliance with the Regulation D-2 performance standard (International Maritime Organization 2013a).

3.5.2 Current management at the border

New Zealand introduced mandatory controls on the discharge of foreign ballast water in New Zealand territorial waters in 1998 in the form of an Import Health Standard for Ships' Ballast Water from All Countries (BW IHS). The BW IHS was updated in 2005, and remains in force. It applies to ballast water loaded within the territorial waters of a country other than New Zealand and intended for discharge in New Zealand waters. It does not currently apply to ballast water loaded in New Zealand waters or to an emergency discharge of ballast water.

Ballast water from another country can only be discharged into New Zealand waters with the permission of an inspector where it can be demonstrated that the ballast water:

- has been exchanged *en route* to New Zealand in areas free from coastal influences, preferably 200 nautical miles from the nearest land and in water over 200m in depth or,
- is freshwater or,
- has been treated using a shipboard treatment system approved by MPI or,
- is discharged in an onshore treatment facility approved by MPI.

Only the first two options are currently viable as there are no shipboard treatment systems or onshore facilities approved by MPI. However, this may change as the IMO has now accredited a number of ballast water treatment systems for use on international vessels (see Section 3.5).

Ballast water exchange involves emptying and refilling ballast tanks to an efficiency of 95% volumetric exchange, or pumping through the tanks a water volume equal to at least 3x the tank capacity. Sediment that has settled in ballast tanks, ballasted cargo holds, sea-chests, anchor lockers or other equipment must not be discharged into New Zealand waters. The Master of the vessel must complete a Vessel Ballast Water Declaration before arrival in New Zealand to provide the evidential basis for how ballast water has been managed on board the vessel.

Exemptions from the conditions of the BW IHS may be granted to allow discharge of ballast water when it can be demonstrated that the weather conditions on the voyage in combination with the construction of the vessel have precluded safe ballast water exchange. Where this has occurred and the vessel is carrying ballast from areas considered a particularly high risk (currently Port Phillip Bay and Tasmania), the vessel must either redistribute the ballast water around the ship's ballasting spaces in order to load cargo or, if this is not possible to accomplish with a suitable margin of safety, the ship must leave New Zealand without loading some, or all, intended cargo (MAF Biosecurity New Zealand 2007b).

3.5.3 Proposed management of ballast water on domestic or short regional voyages

Australia

Ballast water taken up within Australia's Territorial Sea and domestic ports is managed by the State or Territory Government agencies responsible for the port location. In an effort to harmonise national arrangements for the management of domestic ballast water, the Commonwealth Department of Agriculture Forestry and Fisheries (DAFF) commissioned an assessment of interim measures for domestic management of ballast until Regulation D-2 of the BW Convention comes into force (Gust et al. 2005). The interim measures considered were:

- **No change** to existing policy (i.e., no additional measures to manage domestic ballast).
- **Mandatory exchange** of domestic ballast water at sea, irrespective of risk or the length of voyage.
- **Risk-based exchange** whereby only vessels assessed as high risk would be required to exchange ballast at sea.

Risk would be assessed on a tank-by-tank basis for each vessel, based on risk tables developed for known harmful marine organisms. The tables considered risks from eight harmful organisms known to be in Australian waters and took account of:

- The prevalence or absence of known problem species in the source port at any particular time of year.
- The prevalence or absence of known problem species in the proposed destination port or ports.
- The climatic and environmental conditions for establishment at the destination port or ports.
- If exchanging ballast water is required, it will need to meet particular standards.

Four options were also considered for the location of ballast water exchange to occur.

- Within designated exchange areas.
- Beyond 50 nautical miles or in waters 200 m deep.
- Beyond 12 nautical miles.
- Beyond 3 nautical miles.

Analysis of the costs and benefits of each option suggested that the costs associated with ballast water exchange (initial costs) were determined by how far off the standard route a ship must divert to perform exchange, with associated costs of fuel (including pumping) and delay. Extra costs to government consisted of ballast water and logbook inspections and the maintenance of the risk assessment tool and ballast water management database. Maintenance of the risk assessment tool would require monitoring of ports for the presence of harmful organisms. Costs were also expected to vary geographically, among states (Knight et al. 2007). The total cost to Australia of implementing mandatory exchange was estimated to range from AUS$30.5 million per annum (for exchange at 3 nm) to AUS$72.7 million per annum (for exchange at 50 nm/200 m). The reduction in risk of an incursion attributable to ballast water exchange was uncertain, but was assessed to be considerably higher in appropriately designated zones and at 12 nm or beyond (>80% reduction). On average, exchange at 3 nm was assessed as being <70% effective (Knight et al. 2007).

The State of Victoria, Australia

The Australian State of Victoria has already implemented a risk-based system to manage domestic ballast water. If domestic ballast water is intended to be discharged within Victorian waters (i.e., within 12 nm of the coast) and ports, the Master of the vessel must assess the risk of the ballast using an online risk assessment tool (the Australian Ballast Water Management Information System). Vessels with ballast assessed by the tool as ‘high-risk’ must treat the water using a method approved by the Victorian Environmental Protection

Authority (EPA) and obtain written approval from the EPA prior to discharge (EPA Victoria 2010).

Approved methods of treatment include:

- BWE outside Victorian State waters (at least 12 nm off the Australian coast) using "sequential" (empty/refill), 'flow-through' or 'dilution' methods, or
- on-board treatments that have been pre-approved by the EPA.

Vessels that are regularly trading in Victorian ports may enter into an accreditation agreement with the EPA. To do so, the ship's owner and master must have demonstrated, to the satisfaction of the Authority, a high level of performance in domestic ballast water management. The ship's master(s) must demonstrate a good understanding of the statutory requirements for domestic ballast water management in Victoria. An accreditation agreement specifies journeys and ballast water management arrangements that will be exempt from the standard reporting requirements in the ballast water Regulations and policy.

The administrative costs of implementing Victoria's domestic ballast water policy, which include a compliance monitoring programme, are underpinned by the collection of a fee from all ships visiting Victorian ports that have the capacity to carry marine ballast water. Accredited ships pay reduced fees, to reflect a reduced need for service from EPA (EPA Victoria 2010).

Europe

There is no coordinated EU ballast water policy and no legal mandatory requirement in place for ballast water exchange or treatment (David & Gollasch 2008). Instead, a range of voluntary regional initiatives have been implemented that variously cover the north east Atlantic and the Baltic Sea, the Adriatic Sea, the Black Sea and Caspian Sea (David & Gollasch 2008). Although these regional agreements are in different stages of development, each requires vessels travelling into the region to undertake BWE or treatment prior to entry and before discharge can occur (David & Gollasch 2008).

California

In the State of California, U.S.A., requirements for ballast water management apply to all vessels >300 GT, but vary depending upon whether the vessel arrives from within or outside the Pacific Coast region of North America and whether the ballast has been sourced from within the Pacific Coast region. Vessels arriving from outside the Pacific Coast Region or which are carrying ballast from outside that region must manage their ballast in one of the following ways.

1. Retain the ballast (no discharge).
2. Exchange ballast water in **mid-ocean waters** (waters more than 200 nm from land at least 2,000 m deep) by either:
   - Empty refill (100% volumetric replacement), or
   - Flow through (300% volumetric replacement) methods.
3. Discharge ballast water at the **same location** where the ballast water originated. (i.e., within 1 nm of the berth or within the recognised breakwater of a California port or place at which the ballast water was loaded).
4. Use an alternative, environmentally sound method of treatment approved by the California State Lands Commission (CSLC) or US Coast Guard.

5. Discharge to an approved reception facility (none currently exist).
6. Under extraordinary circumstances, perform a ballast water exchange within an area agreed to in advance by the CSLC.

For vessels arriving from within the Pacific Coast Region, options 2) and 3) above have been modified to allow:

2. Exchange of ballast water loaded in the Pacific Coast Region within **near-coastal waters** (i.e., waters more than 50 nm from land at least 200 m deep), or
3. Discharge at the **same port or place** where the ballast water originated (i.e., within 1 nm of the berth or within the recognised breakwater of a California port or place at which the ballast water was loaded).

These are seen as interim measures and California has recently proposed amendments to its rules governing the discharge of ballast water that will see the phased implementation of ballast water performance standards for all vessels >300 GT by 2016. The proposed standards mirror those contained within Regulation D-2 of the BW Convention, but contain more stringent requirements for the concentrations of living organisms in the treated discharge.

3.6 Assessment of options – ballast water

3.6.1 Ballast Water Exchange (BWE)

Effectiveness

Although there is consensus that BWE reduces the supply of potentially harmful marine species discharged into ports, there is still some debate about its effectiveness because of variability in the extent to which risk is reduced (Costello et al. 2007, Gray et al. 2007, McCollin et al. 2007, Ruiz & Reid 2007). A review of scientific studies of BWE undertaken by Ruiz & Reid (2007) suggests that, when it is performed properly, BWE can remove 88-99% of the initial water from the ballast tanks. Concentrations of coastal plankton may be reduced by an average of 80-95% across ship types and many taxonomic groups, with the lowest reductions observed for empty-refill BWE on containerships.

The effectiveness of BWE is less clear for waterborne bacteria, viruses, and protists (other than dinoflagellates) and for short-voyage exchange of coastal waters, with some studies finding no significant reduction following BWE (Drake et al. 2002) and others variable results (McCollin et al. 2007).

Location of exchange

The requirements for BWE to occur at least 50 nm from the nearest land and in water at least 200 m depth, as set out in the BW Convention, cannot be met by most coastal shipping in New Zealand without significant deviation from schedule and potential delay. Several studies have attempted to identify areas closer to the coastline where BWE might be possible.

Chiswell et al. (2001) used output from a numerical model of the tides and analysis of data from current meters moored in the coastal zone and two surface drifter tracks to identify possible areas within New Zealand's Territorial Sea (12 nm) for BWE. Their analysis was based on the speed with which discharged ballast might reach the coastline and did not consider the effects of dilution on the likely establishment of planktonic propagules. They concluded that, except for the east coast of the North Island, the maximum displacement times for particles were too short to expect discharge to be advected away from New Zealand quickly enough to eliminate the prospect of harmful organisms establishing.

Highest risk areas for discharge were judged to be off the northeast coast of the North Island between North Cape and Bay of Plenty. Lowest risk was the area between East Cape and Mahia Peninsula (Figure 3-1).

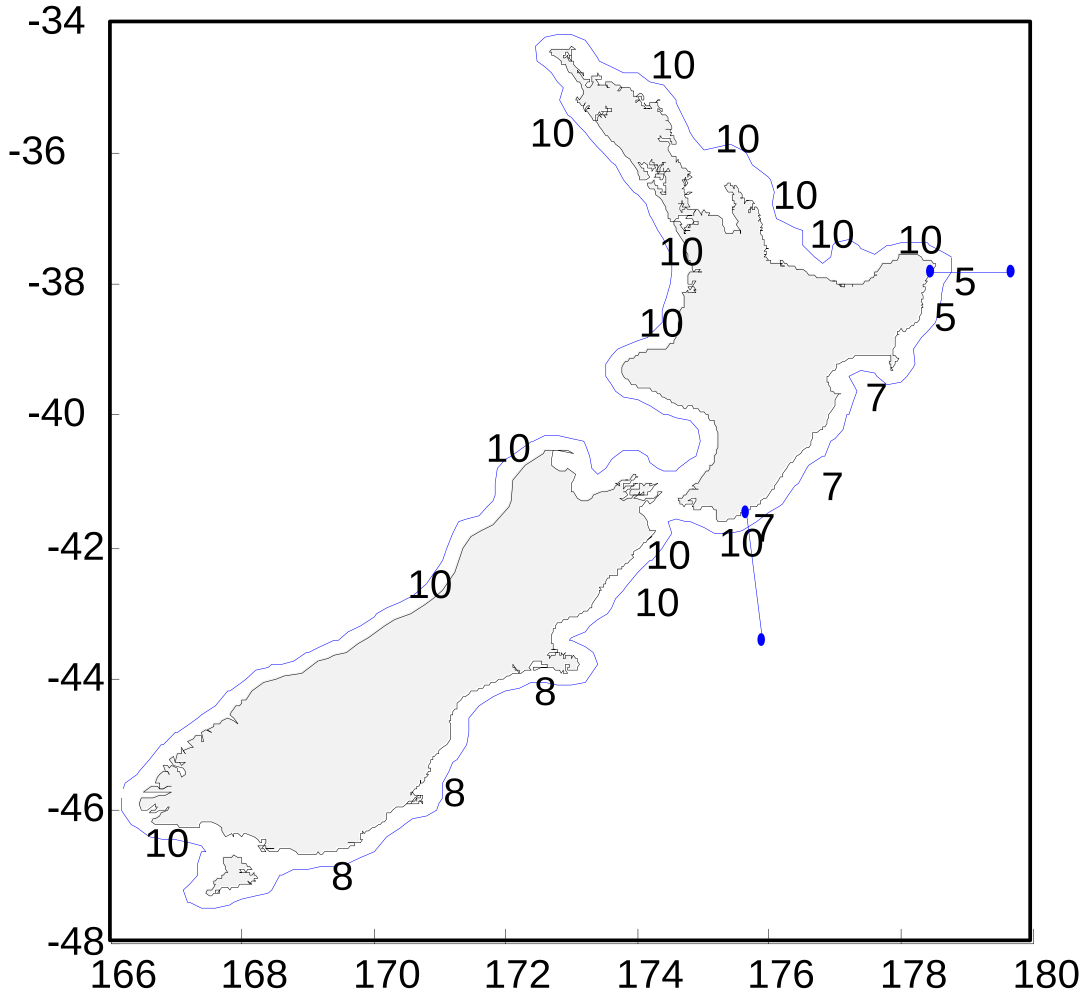

Figure 3-1. Relative risk factor for discharge within the 12 mile limit. A factor of 0 would indicate no risk to the environment, and 10 indicates almost certain advection to the coastline. Lines indicate the approximate limits of the least-risk coastal zone for ballast discharge (Source: Chiswell et al. 2001).

In Australia, Knight et al. (2007) modelled expert judgement of the reduction in risk achieved by undertaking BWE at 3, 12 and 50 nm from the coastline. They estimated that a boundary of 3 nm reduced risk of an incursion by an average of 60% and would have a minor impact on the shipping industry. A boundary of 12 nm provided an average risk reduction of 75%, and had a moderate impact on the shipping industry. A boundary of 50 nm reduced the average risk by a further 10%, but imposed a significant cost on industry (Knight et al. 2007). No similar studies have been done for the New Zealand coastline.

Practical feasibility

Most large merchant vessels are able to carry out BWE without needing additional plant to be installed. However, exchange operations on larger vessels may take up to 1–3 days making it impractical for voyages of short duration, without imposing delays on the vessel

(Gollasch et al. 2007). Because of the short distances between New Zealand ports, transit times will often be shorter than the time required for effective BWE.

New Zealand does not have a mandatory system of shipping routes around the coastline. Maritime New Zealand has introduced a voluntary code for ship routeing that applies only to oil and chemical tankers passing through New Zealand's coastal waters (Land Information New Zealand 2012). The code recommends that ships keep at least 5 nm away from land, any charted danger and any outlying islands, until they reach a position where they are required to alter course to make port. It also recommends approach routes to the major New Zealand ports, and identifies safe minimum distances from known hazards during the approach. The code also contains details of IMO approved ships' routeing measures that are active in New Zealand. These include special *Precautionary Areas* off the Taranaki coast, where vessels must navigate with particular caution and two *Areas to be Avoided* because of the risk of pollution and environmental harm (around the Three Kings and Poor Knights Islands).

Safety is of paramount importance for vessel operations and BWE may only be undertaken when it is safe to do so. For some sections of the coastline (e.g., Foveaux Strait, the Southern Ocean), conditions suitable for BWE may occur infrequently.

3.6.2 Ballast water treatment

The use of IMO approved treatment systems would require expensive retrofitting of the current fleet operating New Zealand's coastal trade (see the following section on Cost of compliance). Companies that operate small domestic fleets are unlikely to be in a financial position to adopt these technologies in the short-term.

Other, cheaper forms of ballast treatment might, however, be more feasible. For example, ballast tanks could be dosed with chlorine prior to discharge. A chemical treatment requirement may be feasible to implement and enforce from an agency perspective. Verification would be needed to determine that the treatment was applied and that it was effective. This could be done through audit of ship-board records and sampling of treated tanks or discharge.

Some research might be required to assess whether discharge of chemically treated water would, over time, have significant adverse effects on marine life, and to identify a list of chemicals for approval under the Biosecurity Act, RMA and HSNO Act. US Coast Guard has recently approved some systems that involve chemical treatment of ballast discharges so there may be opportunities to build upon research already done[3].

3.6.3 Designated locations for discharge

If preferred locations for discharge were on common shipping routes and voluntary, it would be practical for most vessels to comply without significant cost. However, providing guidance on preferred locations for discharge could prove problematic for councils as stakeholders who may potentially be affected by the arrival of a harmful marine organism are unlikely to want "designated discharge areas" in their region. Consequently, any designation of discharge areas would need to be supported by strong scientific justification.

Conversely, if prohibited discharge areas were to be identified, there is likely to be pressure to define these widely, but this would make the measures burdensome and impractical for shipping. Ideally exchange areas need to be large enough for full exchange to occur while the vessel is in motion. Full volumetric exchange requires up to 3 d for large vessels (Gollasch et al. 2007) and will not be possible for most short duration trips. It may be practical for individual tanks to be exchanged before the next port of call.

[3]http://www.uscgnews.com/go/doc/4007/1749835/Coast-Guard-accepts-ballast-water-treatment-systems-as-Alternate-Management-Systems

3.6.4 Accreditation schemes

Accreditation schemes would seem, in principle, to have high feasibility (i.e., there are no obvious operational reasons why ships could not develop and implement vessel biosecurity management plans). But until such a scheme is in place and been shown to be both practical and credible, it is premature to draw conclusions about such an option.

Cost of compliance

Requirements for mid-ocean exchange of ballast water would be very costly if imposed on domestic routes, as vessels would have to lengthen their voyage to comply (See Section 3.6.1). The cost of complying with guidance on preferred discharge areas or requirements to avoid specified areas will depend on the extent of the areas defined, with costs ranging from negligible to prohibitive if they required significant detours. Exchange areas need to be large enough for full exchange to occur while the vessel is in motion. Small areas may mean a vessel has to back-track to achieve full volumetric exchange.

Costs of complying with the D2 treatment standard depend on what treatments are applied. In 2007, the Australian Centre for International Economics (2007) suggested that the capital cost for a vessel to install a treatment system could range from around AUS$1 million to AUS$5 million. As most international shipping will be required to install this equipment for movement between Port States, the extra capital costs within New Zealand will be for those New Zealand domiciled vessels that undertake only domestic voyages. The ongoing operating costs for a treatment system have been estimated to be between 0.06 cents and 4.66 cents/t of ballast water treated (Centre for International Economics 2007). The ongoing costs for alternative treatment systems are not known and would require further research before implementation. A more recent survey of approved ballast water treatment systems estimated the purchase costs across different types of treatment systems and categories of ship types/sizes to range between US$640,000 to US$947,000 (i.e., ~NZ$77,0000 to NZ$1.14 million) (King et al. 2012). Installation costs will vary widely depending on the ship's size and design. Annual operating costs for maintenance of the treatment systems were estimated to range between US$9,000 to US$17,000, depending on vessel type and size (King et al. 2012).

Compliance costs associated with accreditation schemes are also difficult to assess until such a scheme is in place. Costs would be imposed on government to verify and audit compliance with the system and these are likely to be passed on to ship operators. In the Australian State of Victoria vessels with an accredited ballast water management system pay a reduced administration fee to the State government and are exempted from reporting requirements for regular, accredited routes (EPA Victoria 2010). An accreditation scheme may have some additional benefits to vessel operators, however, if they can use their accreditation in promotional material. For example, the international ship vetting company, *RightShip* Pty Ltd, now offers an environmental rating to help charterers and purchasers make decisions about vessels, where environmental sustainability is a key part of those decisions. Although the rating is currently based on energy efficiency and CO_2 emissions by the vessels, there is a possibility of extending it to include other areas of environmental performance.

Expected rate of uptake

Mandatory measures that are practical to monitor and enforce, even if they are high cost, are likely to have a high rate of uptake. This could apply to requirements for ballast water treatment, depending on the approved systems, whereas it could be more difficult to enforce prohibitions on discharges in specified areas if these are near shipping lanes.

Uptake of accreditation schemes, if voluntary, would be moderately low initially and build over time if the benefits to participants of accreditation are realised. For example, the Marine Stewardship Council fishery certification scheme has, after 13 years, resulted in the certification of 200 fisheries worldwide, but this still represents only 8% of the global wild harvest[4]. The shipping industry is far more concentrated than fisheries, so support from a few major players could result in a high level of uptake. For example, members of the World Shipping Council (WSC) account for approximately 90% of the global container ship capacity, and collectively transport about 60% of the value of global seaborne trade annually. The WSC is already engaged internationally with the IMO and national governments in implementing measures to reduce the global spread of invasive marine organisms. Uptake of any domestic measures by international shipping will be greatest if it is consistent with agreed IMO conventions and guidelines.

Other considerations

One of the considerations identified by participants in the first workshop was alignment with measures being implemented at the New Zealand border and internationally. This would suggest not getting ahead of the entry into force of IMO rules or at least ensuring that shippers have practical and reasonably low cost ways they can meet any treatment requirements that are not more stringent than requirements at the border.

3.7 Available practices to reduce risk - bilge

Because there have been few specific studies of the biosecurity risks from the transport of bilge there is, to our knowledge, no assessment of the efficacy of potential treatment methods. Water contained in the bilge and other engine spaces will be contaminated with oils and other waste liquids. It is unclear how toxic bilge water may be for organisms within it and how much this will reduce biosecurity risk.

Annex I of the *International Convention for the Prevention of Pollution from Ships*, 1973/1978 (MARPOL) stipulates that vessels of 400 GT or more must have approved oil filtering equipment installed and that bilge water discharged into international waters must contain no more than 15 ppm oil (Regulation 16(5)). New Zealand has implemented corresponding rules under the Maritime Transport Act 1994 and the Resource Management (Marine Pollution) Regulations 1998 to enable these requirements within New Zealand waters. Internationally registered vessels are required to meet the MARPOL discharge standard (Maritime New Zealand 2009). New Zealand registered vessels of 400 GT or more must have oil filtering equipment, approved by the Director of Maritime New Zealand, which is designed to ensure that discharged water has an oil content that does not exceed 15 ppm (Maritime New Zealand 2011e). Vessels <400 GT must meet the discharge standard for larger vessels or be able to retain all oily wastes on board for discharge to a reception facility on shore (Maritime New Zealand 2009).

A range of different technologies is used on large vessels to separate oil from waste-water. Some of these treatment systems may also reduce the risk of transporting harmful marine organisms, but this remains to be assessed. Conventional systems use static holding tanks to allow oil droplets to separate from the water due to their different viscosities. However, these technologies are not capable of meeting the 15 ppm discharge standard (Mahle Industrial Filtration 2008). Other technologies employ membrane filtration, centrifugation, adsorption on active carbon granules, heating, ultra-sonic energy, electro-coagulation and chemical methods such as Wet Air Oxidation Zimpro Process (Mahle Industrial Filtration 2008). In-line filtrations systems that connect to the bilge pump discharge line are also available for medium sized and smaller vessels (including recreational vessels). Again, there is a variety of products on the market. Systems that use filter cartridges utilise a range of different types of filter materials. The Mycelx® filters, for example, have a pore size of 5 µm and are advertised as being capable of reducing oil concentrations in the discharge line to 5 ppm.

Where bilge-water treatment systems are not present, treatment of bilge water spaces with an approved disinfectant before the vessel moves to a different site/region may also be an option.

[4] http://www.msc.org/business-support/key-facts-about-msc

Four practices are recommended for treatment of bilges and water in other contained spaces to reduce biosecurity risks.

- Discharge and emptying of water before departing from a location.
- Retention and storage of water for discharge to shore-based treatment.
- Regular flushing with freshwater or an approved treatment as a preventative measure to keep the spaces clean.
- Treatment of water spaces with an approved treatment (Cawthron Institute 2013, Commonwealth of Australia 2009b, International Maritime Organization 2012, MAF Biosecurity New Zealand 2007a).

The first three of these options are generally preferred over chemical treatment of water spaces.

3.8 Assessment of options – bilge

3.8.1 Effectiveness

There is a need for more research and guidance on the level of risk posed by seawater held on vessels and on the effectiveness of different methods for reducing the biosecurity risk (e.g., filtration, chemical treatment, flushing, etc.). As described in Section 3.7, technologies used by commercial vessels to separate oil from waste-water will provide some reduction in biosecurity risk, but the level of risk reduction is uncertain.

A range of commercial marine detergents, grease removers and disinfectants is available in New Zealand that are used in some boating sectors (e.g., Simple Green®, Salt Free Bilge Cleaner®, SeaWise Grease Remover®, WAMO Marine®). Different products are marketed for cleaning and disinfecting different types of wet surfaces including bilges, deck surfaces, holds, bait boxes, and fish bins. However, the Ministry for the Environment and Ministry of Tourism (unknown), the New Zealand Marina Operators Association (2008) and Maritime New Zealand do not recommend use of bilge cleaning products as they can be toxic to marine life and disperse the oil contained in the bilge rather than remove it. Instead, the recommended practice is to retain the seawater and pump it out to shore-based treatment facilities (where available), rather than discharging at sea and, where necessary, to use enzyme-based bilge cleaners in preference to detergents.

For vessels with automatic bilge pumps, installation of in-line filters is recommended to remove contaminants. In-line filters are likely to provide some protection against discharge of harmful organisms by removing larger organisms and/or fragments from the discharge stream, but it is unclear how effective they would be at retaining planktonic propagules. A range of filter types is available commercially for vessels of different sizes.

Potentially, bilge water could be treated with methods similar to those used to treat biofouling within internal seawater systems on vessels. These could include vinegar, disinfectants, bleach or other chlorine-based products. For example, guidelines developed for the management of seawater discharges in the Fiordland Marine Area recommend treating bilge with bleach (5% sodium hypochlorite) at a concentration of 1 part per 100 parts of seawater. The disinfectants *Conquest* and *Quatsan*, both of which contain the active ingredient benzalkonium chloride, are effective for treating biofouling in internal piping (Lewis & Dimas 2007) and are also likely to be effective against planktonic stages within the seawater. Grandison et al. (2012) reviewed the efficacy of a range of other oxidising and non-oxidising biocides that's may be used to treat biofouling in internal water spaces.

Internal seawater piping systems and intakes, including sea-chests and strainer boxes, may also contain significant volumes of seawater and are susceptible to growth of biofouling. Large merchant vessels often have Marine Growth Protection Systems (MGPS) installed that use sacrificial anodic copper dosing (e.g., Cathelco® systems) or chlorine injection to treat these internal spaces. A recent review of MGPS for the Royal Australian Navy suggests that while these systems do provide some protection against heavy fouling they are not effective in all situations and require regular maintenance to ensure effective operation (Grandison et al. 2012).

Where a MGPS is not installed, treatment of internal seawater systems is best done when the vessel is slipped, using disinfectants or descalers. For smaller vessels, regular flushing of internal systems with freshwater or a mixture of boiling water, ¼ cup of baking soda and ¼ cup of vinegar may help prevent the build-up of biofouling (New Zealand Marina Operators Association 2008). Treatment is recommended when the vessel has been stationary for an extended period of time and before it is moved to a new location (Cawthron Institute 2013, Commonwealth of Australia 2009b).

3.8.2 Practical feasibility

For operational safety, most bilge systems operate continuously although there is usually an option to switch to manual mode for at least short periods. It may, therefore, be feasible to manage the discharge of bilge water in specific areas such as Fiordland (Cawthron Institute 2013). If bilge pumping could be done only in designated areas, this may be effective in reducing risk to high value areas.

These procedures might be appropriate for vessels such as cruise ships and commercial fishing vessels visiting high value areas but less relevant and less feasible for merchant cargo vessels.

3.8.3 Cost of compliance

The costs of compliance are likely to relate more to operational procedures than to financial outlays. If feasible practices can be identified, the costs of implementation could be relatively modest. There will be associated costs to government or regional authorities in verification and auditing of compliance with the recommended measures.

3.8.4 Expected rate of uptake

Consultation undertaken as part of work by Cawthron for MPI has highlighted that most vessel operators in Fiordland perceive bilge water as unimportant from a biosecurity perspective (Cawthron Institute 2013). While this work was mostly with recreational vessels, we have no reason to expect a higher awareness amongst merchant vessels. Given this, irrespective of practical feasibility and efficacy, compliance with any bilge water measures might well be low and, perhaps more importantly, non-compliance would be difficult to verify. Research is needed to quantify the actual risk from bilge water to determine what type of measures might be appropriate.

To achieve a high uptake, therefore, measures to manage bilge water would need to be simple and practical. The actual risks associated with transport of bilge and methods for managing them need to be communicated widely.

3.8.5 Other considerations

The use of bleach, chlorine or other chemicals for treating bilge water would need to be assessed by any agencies recommending its use to determine their likely effects on marine life if used widely. Any recommended treatments would be required to meet the conditions of the HSNO Act and Marine Pollution Act.

3.9 Available practices to reduce risk - biofouling

3.9.1 International Measures

International Maritime Organisation (IMO)

In 2011, the Marine Environmental Protection Committee of the IMO adopted a resolution that detailed *Guidelines For the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species* (MEPC.207(62)). The guidelines recommend measures that vessel operators can take to minimise the risks of transporting biofouling. These include guidance on appropriate choice and maintenance of anti-fouling systems for vessels and operational practices to reduce the development of biofouling. A central feature is maintenance of a Biofouling Management Plan (BMP) and record book for the vessel that details how it manages biofouling. The BMP should document the vessel's schedule of surveys and hull inspections, replacement of anti-fouling systems, dry-docking, and any in-water cleaning that contributes to reduction in the build-up of biofouling. Although the guidelines are voluntary, the IMO has urged Member States to take "urgent action" to apply them including their dissemination to the shipping industry and other affected parties.

Australia

In 2009, the Commonwealth Government of Australia released a series of guidance documents, with state and territory governments, on biofouling management for different sectors. Separate documents were developed for recreational, fishing, commercial and non-trading vessels, and the petroleum production and exploration industry (Commonwealth of Australia 2009a, 2009b, 2009c). Their purpose was to assist each sector to manage its own risks by providing practical advice on how to reduce the transport of biofouling through regular inspection and cleaning of vessels and gear and by appropriate use of anti-fouling coatings. Uptake and implementation of the guidance by each sector was voluntary.

The Commonwealth Government has since sought comment on proposed national regulations on biofouling management (Pricewaterhouse Coopers 2011). Under the proposal, all vessels entering Australian waters would be required to provide information on the following.

- The type and age of anti-fouling coating it used.
- Use of treatment systems for internal seawater.
- Recent hull surveys or inspections of biofouling.
- Duration of stay in overseas ports.
- The time anticipated in Australian waters.

The information would be used to assess risk from the vessel using an online risk assessment tool. Vessels assessed as "high" or "extreme" risk would be subject to restrictions on the time they could operate at any one port (48 h), at a series of ports (8 days total) or within Australian waters (14 days). If the vessel was unable to conduct its business within these restrictions it would be required either to leave Australian waters or be subject to a hull inspection to determine if any quarantinable marine organisms ("Species of Concern"; SoC) were present. Fifty six SoCs have been identified that the Commonwealth Government proposes to manage and some states have their own lists of species of concern (See the following section on Australian States & Territories).

Australian States & Territories

Western Australia (WA) and the Northern Territory (NT) currently have policies to manage biosecurity risks from biofouling on vessels entering their waters (Pricewaterhouse Coopers 2011). The NT protocol currently applies only to recreational vessels.

WA has the most stringent requirements. It is an offense under the WA *Fish Resources Management Act of 1994* (FRMA) and associated regulations to transport species that are not native to WA without written approval from the Director General of the Department of Fisheries. Western Australian policy dated March 2013 states "Our policy is that all vessels (including recreational vessels) must be 'clean' before their trips start."[5] As written, the policy applies to interstate and intrastate movements as well as international movements of vessels. Owners and masters of vessels arriving at WA ports are required to ensure that harmful marine organisms are not being carried in biofouling. To this end, the FRMA enables WA authorities to request evidence that a vessel is free from introduced marine pests, to place restrictions on movements and time in port and to recover costs from persons considered responsible for the biological threat. Evidence that must be provided for a risk assessment to demonstrate a vessel is free of harmful organisms includes the following.

- Log entries or a BMP that document the vessel's operational history since it was last antifouled or inspected.
- The most recent in-water cleaning, dry-dock slip or in-water inspection report.
- Evidence of appropriate, functional treatment systems for seawater intakes, sea-chests and sea strainers (e.g., marine growth prevention systems or manual treatment regimes).
- A certificate of the most recent anti-fouling coating applied (or original receipts that describe the coating type(s) and its application).

The approach taken by Australian state governments differs from that taken by New Zealand and California in that it focuses primarily on risks from particular Species of Concern (SOC). New Zealand and California both seek to manage for a level of biofouling, without direct recourse to species identity, whereas WA and NT both have schedules of SOC, listing 101 and 44 species, respectively.

California

The US State of California has published draft regulations for biofouling management for vessels entering its waters. These were expected to come into force in 2013 and then to apply to vessels >300 gross registered tons from 1 January 2014 (after first dry-docking), but are currently under review (California State Lands Commission 2012b). The proposed regulations include requirements for vessels to maintain a BMP and a biofouling record book. They also specify performance standards for how clean the vessel must be prior to arrival. The standards require the percentage cover of macrofouling (visible organisms) to not be 'significantly in excess of':

- 1% of the wetted general hull surface area of the vessel and
- 5% of the wetted area of niche structures, such as sea-chests, bow thrusters, rudder, grills, etc.

Compliance with this standard can be demonstrated through information provided in the BMP and record book, which should be able to demonstrate that the vessel has an anti-fouling

[5] http://www.fish.wa.gov.au/Documents/biosecurity/introduced_marine_pests_management_guidelines.pdf, accessed 21 August 2013.

system that is appropriate for the operational profile of the vessel **and** that biofouling on the vessel has been evaluated and cleaned if necessary:

- no longer than six months prior to arrival to a California port or place, or
- no longer than 12 months prior to arrival to a California port or place if:
  - the vessel was delivered as new within the twelve months prior to arrival; or,
  - the vessel underwent full application of one or more anti-fouling coatings during out-of-water maintenance and was refloated within the twelve months prior to arrival.

A vessel deemed to be in 'gross exceedance' of the performance standard may be required to be cleaned prior to its next entry into a Californian port. A 21-day period of grace commencing on the date of violation is given to allow for scheduling and implementation of cleaning activities.

3.9.2 Management at the Border

The New Zealand Government is working toward introduction of a *Craft Risk Management Standard* (CRMS) that will specify requirements for managing risks from biofouling and ballast water on all vessels entering New Zealand Territorial waters. The standard will be phased in to allow time for vessels to adopt the IMO Guidelines (Section 3.9.1) and for better technologies and capability to be developed for hull maintenance and cleaning within New Zealand and overseas. In the interim, MPI will take action only against vessels with biofouling that are considered to pose a "severe risk" to New Zealand resources.

From the date of release of the CRMS, all vessels will be required to complete a biofouling declaration prior to entering New Zealand. This will provide information on the vessel's recent operational profile, its biofouling management history and intended period of stay in New Zealand. When the CRMS comes into force, all vessels will be required to have a 'clean' hull on arrival. Clean will be defined as allowing only limited biofouling growth, but there are likely to be different thresholds of allowance for vessels with short turnaround in New Zealand ports (e.g., commercial ships passing through) and those intending on longer stays. The latter will be allowed only a slime layer and goose barnacles.

The CRMS will contain guidance on how to meet the standard and details of proof that can be presented to speed clearance. Compliance may be achieved in several ways.

- Through adherence to an industry Code of Practice (CoP) that has been approved by government.
- By preparation and submission of an approved Biofouling Risk Management Plan.
- Through specific arrangements (e.g., where vessels can demonstrate, through auditable records, that they operate a biofouling management regime that complies with the IMO guidelines).
- Through any method that has received prior approval by MPI.

3.10 Assessment of options - biofouling

3.10.1 Measures to reduce biofouling risk

Several recent studies have reviewed available practical options for removing biofouling from vessels in New Zealand (Bohlander 2009, Floerl et al. 2010, Inglis et al. 2012). These include de-fouling in land-based shipyards and various methods of in-water cleaning (see Table 3-2).

3.10.2 Ship-yard facilities

Effectiveness

Dry-docking of commercial vessels and out of water maintenance would normally occur in commercial facilities, and painting is often under the technical supervision of the anti-fouling paint supplier.

Haul-out and high-pressure water-blasting is an effective method for removing biofouling. The power of the water-blast may be varied depending on the type of anti-fouling coating on the hull (e.g., silicone based paints require gentler treatment), but is usually up to 8,000 psi (Floerl et al. 2010). Water-blasting is less effective for treating biofouling in recessed areas, such as seawater inlet pipes and gratings. These niche areas may be treated using other methods, such as flushing with detergents or chemicals (e.g., bleach) (Section 3.10.4) or, in the case of sea-chests, through removal of the outer grating and water-blasting the inside of the chest. When vessels are hauled out for cleaning there is the risk that mobile organisms within the biofouling will escape and that some sessile organisms will be dislodged when the vessel enters the cradle (for slipways) or slings (travel-lifts) (Coutts et al. 2010).

Practical feasibility

There are only three shipyard facilities in New Zealand capable of removing large vessels (>1800 DWT) from the water. These are located in Lyttelton, Auckland and Whangarei and are capable of handling vessels up to 180 m length and 24 m beam (Table 3-2; (Inglis et al. 2012). Vessels larger than this would need to travel offshore for cleaning.

A summary of shipyards and haul-out facilities available in New Zealand for vessels <1,800 DWT) is provided in Appendix 1. Most of New Zealand's domestic commercial vessels can be accommodated in haul-out facilities within New Zealand, with the exceptions of the inter-island ferries and coastal tankers (Rockpoint Corporate Finance Ltd 2009). These haul-out and dry-dock facilities are, however, in high demand and require advance booking. Most foreign passenger and merchant vessels that operate in New Zealand are too large to be accommodated by New Zealand's dry-dock and haul-out facilities (Inglis et al. 2012).

Cost of compliance

The costs associated with slippage or dry-docking and removal of biofouling depend on the size of the vessel. Indicative costs for vessels of different sizes are presented in Table 3-3 and Table 3-4. The total cost can be up to NZ$38,000 for vessels >5,000 GT in addition to up to 3.5 days of lost revenue when biofouling is removed by water-blasting (Table 3-4). Removal of a large merchant vessel from the water, in dry-dock, floating-dock or slip way, and cleaning of biofouling usually requires 1 to 3.5 days of operations when the cleaning is done by water-blasting.

There are also expected to be costs to government associated with monitoring compliance with any biofouling requirements and in auditing containment and treatment of waste.

Expected rate of uptake

Because of the direct costs associated with haul-out of large vessels and the indirect costs accrued through lost revenue or down-time, operators of large vessels will be reluctant to undertake out-of-water cleaning outside scheduled survey and service periods.

3.10.3 In-water cleaning

In-water removal of biofouling can be achieved by a range of methods. These include removal by:

- divers using hand tools, such as scrapers,
- mechanical brush systems,
- vacuum systems,
- pressure and cavitation methods,
- heat treatment,
- encapsulation,
- enclosure systems to contain waste removed by divers, and
- modified brush cart cleaning systems that capture waste by vacuum and filtration.

Details of these methods can be found in Bohlander (2009), ES Link Services Pty Ltd (2013), Floerl et al. (2010), Inglis et al. (2012), and Morrisey et al. (2013). A summary of their efficacy is provided in Table 3-2 and below.

Key considerations in the choice of method are the potential for release of toxic chemicals from the anti-fouling coatings and harmful marine organisms from the biofouling into the marine environment. The risks associated with in-water cleaning depend upon the following.

- The type of anti-fouling coating present on the vessel and its age.
- The amount and origin of the biofouling (i.e., whether the species are present in the region).
- Measures used to capture and dispose of organic and inorganic waste removed during the cleaning.

Regular (i.e., 6-12 monthly) in-water cleaning is recommended as a way to prevent the development of biofouling on the submerged surfaces of vessels and movable structures, particularly in areas where protection from anti-fouling coatings may be inadequate (e.g., niche areas, propeller, etc.) (MAF Biosecurity New Zealand 2011). In-water cleaning is not recommended for removal of extensive biofouling growths or when the anti-fouling coatings on the vessels have reached or exceeded their planned in-service period (MAF Biosecurity New Zealand 2011). Moreover, non-biocidal fouling release coatings are highly susceptible to damage from abrasive cleaning and can only be cleaned safely with soft materials or non-contact methods (Holm et al. 2003).

Effectiveness

Hand tools

Removal of biofouling by divers using hand tools is effective only when the organisms occur in small patches and in small abundance or when the vessel has fouling-release coatings on its hull. Removing large aggregations of biofouling using hand tools is likely to result in the release of some organisms into the surrounding environment, particularly motile and soft fouling organisms (Morrisey et al. 2013). As only visible fouling is removed, the microscopic life-stages of biofouling organisms (e.g., new recruits, dormant phases, etc.) will not be treated effectively and friable components, such as the slime layer, may not be captured effectively (Floerl et al. 2010). Prototype hand tools fitted with a shroud and suction pump have recently been trialled for removing biofouling from niche areas of large vessels (ES Link

Services Pty Ltd 2013). Initial results indicate good retention of most biofouling material removed by the tool, but there was still difficulty capturing very heavy, delicate biofouling.

Mechanical brush systems

Single, diver-operated brush units are used to clean biofouling from vessel hulls and small, niche areas of vessels, such as propellers, gratings and dry-dock support strips. Most systems are not designed to capture and treat waste removed from the vessel, but they can be fitted with shrouds and suction hoses to achieve this (Hopkins & Forrest 2008). The Department of Fisheries in Western Australia recently commissioned trials of a prototype portable hull cleaning system for vessels >40 m (ES Link Services Pty Ltd 2013). The system incorporated a diver-operated brush cart with hydraulically powered rotating disks, fitted with either brushes or blades, a vacuum pump and a shroud system to contain debris within the area of suction. Water and material lifted by the hydraulic suction was passed through a two-stage filtration system (to 5 μm) on board the supporting vessel and the secondary filtrate was disinfected by UV irradiation before being discharged. Solid waste was retained for onshore disposal (ES Link Services Pty Ltd 2013). The system is designed for removing biofouling from hull surfaces, but is not suited to treating niche areas. The trials showed that the cart effectively removed light and heavy biofouling from the flat sides and bottom of the vessels, captured biological waste removed from the hull and there was no indication of elevated copper concentrations in the water column near the test vessel during the cleaning (ES Link Services Pty Ltd 2013). It did not remove biofouling near irregularities in the hull (e.g., near welds). The cart also caused some damage to softer, biocide-free, silicone foul-release anti-fouling coatings. Re-design of the cart wheels is needed to mitigate this problem.

Cleaning rates using powered hand tools are estimated to be around 0.3 to 0.6 m^2 per min, depending on the amount and type of fouling, and the experience of the operator (U.S. Army Corps of Engineers 1987). Larger systems, involving underwater cleaning vehicles or carts (Akinfiev et al. 2007, Bohlander 2009), are not currently available in New Zealand.

Pressure (water jet) cleaning

Water-jet cleaning systems are used in the offshore oil and gas industry to remove fouling from structures. Two-types of system are available: (1) a high-flow system that operates at ~1,0000 psi and up to 100 *l* per min, and (2) a smaller, low-flow system that operates at between 3,000 to 1,0000 psi and at 11 *l* per min. High-flow systems are a relatively fast and effective method for removing heavy biofouling from underwater structures. Low-flow water-jets provide a fast and effective means for removing light to moderate fouling (U.S. Army Corps of Engineers 1987). Water jetting is less time-consuming than manual cleaning methods such as scraping and brushing. Cleaning rates of up to 0.75 m^2 per min can be achieved with high-pressure jets (U.S. Army Corps of Engineers 1987), but there is generally no way to retain the biological and contaminant waste removed by them. However, trials have recently been undertaken of a small enclosure system (the “Magic box”) for a 5,000 psi pressure lance that is designed to treat fouling in niche areas of the hull (ES Link Services Pty Ltd 2013). The enclosure is a transparent plastic box that is sealed onto the hull by suction from a hydraulic vacuum. The high pressure lance is inserted into the box once a seal has been achieved. Initial trials experienced difficulty in attaching and sealing the box around protrusions from the hull surface (e.g., anodes), but modification of the shroud attachment system may achieve better results (ES Link Services Pty Ltd 2013).

Heat treatment

At least two proto-type systems have been developed to treat biofouling on vessels using encapsulated heat (thermal shock) (Inglis et al. 2012). Both systems were designed to kill and remove marine slime (biofilm) and algal biofouling on steel-hulled vessels, which they do effectively. They are not intended to treat heavy biofouling and their efficacy for removing aggregations of sessile invertebrates and macroalgae is unknown.

Table 3-2. Summary of methods for removing biofouling from merchant vessels. (Sources: Floerl et al., 2010 and Inglis et al., 2012). More detailed descriptions of the methods and their efficacy can be found in these publications. All values are in New Zealand dollars.

	Availability in New Zealand	Ease of use	Suitable for treating hull areas?	Suitable for treating niche areas?	Effectiveness	Effect on anti-fouling coating	Ability to capture paint and biofouling waste	Time required	Cost	Comments
Land-based shipyards*										
Dry-dock	Lyttelton[1] Calliope (Auckland)[2]	Advance booking required.	Yes	Yes	High	Waterblasting will affect older and damaged coatings.	High	1-5 days	$12,000-$38,000	Old or damaged anti-fouling coatings should be replaced during haulout.
Haul-out	Ship Repair NZ Ltd (Whangarei)[3]	Advance booking required.	Yes	Yes	High	Waterblasting will affect older and damaged coatings	High	1-2 days	$4,000-$16,000	Old or damaged anti-fouling coatings should be replaced during haulout
In-water cleaning										
Manual scrubbing / brushing	Services provided by commercial diving companies.	Specialised equipment needed to capture waste. Requires divers and support vessel.	Generally only effective for 'spot' cleaning of biofouling.	Yes	Varied – depends on the provider.	Potential for damage to coatings.	Generally no.	Depends on vessel size and amount of biofouling.		Predominantly used on recreational and small commercial vessels.
Rotating brushes	Services provided by commercial diving	Specialised equipment needed to capture waste.	Yes	Unsuitable for some niche areas.	Ability to remove all biofouling species from a vessel unproven.	High potential for damage to biocidal coatings.	Generally no. Existing technology to capture and	1-5 days depending on vessel size and	$13,000-$95,000 depending	Can damage ablative and fouling release coatings. Best

	Availability in New Zealand	Ease of use	Suitable for treating hull areas?	Suitable for treating niche areas?	Effectiveness	Effect on anti-fouling coating	Ability to capture paint and biofouling waste	Time required	Cost	Comments
	companies widely available.	Requires divers and support vessel.					retain waste. requires improvement	amount of biofouling.	on vessel size	suited for hard and mechanically resistant coatings.
Underwater suction devices	Custom-built devices in New Zealand, but not widely available.	Requires divers, support vessel and filtration plant.	Yes but only soft-bodied organisms	Unsuitable for some niche areas	Effective for soft-bodied, large ascidians. Ineffective for hard, firmly attached organisms.	None.	Good capture and retention, but expulsion of waste during reverse-flushing when system clogged.			Better suited to soft-bodied taxa. Will not remove hard fouling.
Underwater pressure cleaning	Not available in New Zealand.	Depending on system may require divers (Cavi-Jet). All system require surface support team and filtration plant.	Yes	CleanROV and HISMAR: No. Cavi-Jet: Yes (handheld system only).	Not independently evaluated. Manufacturers/developers admit <100% effectiveness.	None.	CleanROV and HISMAR: Yes. Cavi-Jet: currently none.	1-2 days	$12,0000 depending on vessel size.	Promising technology for hull surfaces, but unsuitable for niche areas.
Heat treatment	Limited availability. Custom-built equipment in NZ. Australian company currently commercialising	Requires surface staff and support vessel. Sea-chest sterilisaton requires retro-fitting the system to	Yes. However, Australian HST method only intended to treat early algal	Unsuitable for most external niche areas. However, sea-chest treatment achievable. HSTNA in development.	Not independently evaluated. Each system effective at killing target biofouling but lacks ability to kill non-target biofouling, heavy biofouling (HST) or niche areas.	None.	Not required.	2-3 days	~$2,00000	Additional R&D may result in systems suitable for niche areas.

	Availability in New Zealand	Ease of use	Suitable for treating hull areas?	Suitable for treating niche areas?	Effectiveness	Effect on anti-fouling coating	Ability to capture paint and biofouling waste	Time required	Cost	Comments
	a heat-based method.	existing vessels.	and slime biofouling.							
Encapsulation	Under development.	Encapsulation with plastic requires divers and can be involved. Installation of ready-made systems (e.g., Improtector) can be quick and easy, no divers required.	Yes.	Yes, including internal seawater systems (IMProtector)	Effective for vessels <20m in length. Application to larger vessels has resulted in some mortality, but has proven difficult to implement effectively.	None.	Yes.	3-14+ days.	$17,000 - $34,000 depending on vessel size and whether chemicals are used to accelerate treatment.	Must be in place for extended periods (days) to be effective. Can be accelerated use toxic chemicals. Effects on coatings undetermined. Does not remove biofouling.
Enclosure system for divers with vacuum and filtration	Under development	Best suited to sheltered conditions as inflatable enclosure is affected by currents. Requires use of divers and other tools within the enclosure	Yes	Potentially, but not internal spaces	Theoretically suitable for large vessels, but field trials equivocal about effectiveness	Depends on the tools used by divers (e.g., hand tools, rotating brushes, etc.)	Yes	2-3 days	Similar to rotating brushes. Depends on the size of vessel	Additional trials required to demonstrate effectiveness
***Envirocart* in-water cleaning system with**	Available in Australia. No	A modified brush-cart system	Yes	No	Effective at removing biofouling from smooth hull surfaces. Incomplete	Caused damage to silicone foul-	Capable of capturing biological		Not specified. Likely to be	ES Link Services Pty Ltd (2013)

	Availability in New Zealand	Ease of use	Suitable for treating hull areas?	Suitable for treating niche areas?	Effectiveness	Effect on anti-fouling coating	Ability to capture paint and biofouling waste	Time required	Cost	Comments
vacuum and filtration	systems present in NZ	operated by divers			removal from hull irregularities, and niche areas.	release coatings	waste removed from the hull, and filtering out and capturing all biological debris and other matter >50 µm in diameter. No evidence of significant copper leaching during cleaning trials		similar to use of rotating brushes	

*Size of vessels able to be accommodated: [1] <137 m length, <14 m beam; [2]<181 m length, <24.3 m beam; [3]<2,000 DWT

Table 3-3. Indicative charges for shore-based removal of biofouling on medium-sized commercial vessels at slipway facilities. Also presented is the estimated time (in days) required for the treatment. Prices exclude GST and are in New Zealand dollars. (Source: Floerl et al. 2010).

Vessel size:	25 m vessel	40 m vessel	60 m vessel
Haul-out	$1,360	$4,160	$9,360
Ship yard charge	$235	$546	$1,360
Water-blast charge	$487	$975	$1,462
Sea-chest cleaning	-	-	$650
Equipment	$390	$585	$975
Labour	$1,360	$2047	$2047
Waste levy	$20	$20	$20
Cost for biofouling removal	$3,770 (1 day)	$8,320 (1 day)	$15,860 (2 days)
Additional cost for anti-fouling	$8,580 (2 days)	$20,150 (2 days)	$32,500 (3 days)

Table 3-4. Indicative charges for dry-dock hire and services for large ships (up to 5,000 Gross Tonnes; GT) at the Lyttelton Port Company's dry-dock in New Zealand. Also presented is the estimated time (in days) required for the treatment. Prices exclude GST and are in New Zealand dollars. (Source: Floerl et al. 2010).

Vessel size:	500 GT	1,000 GT	5,000 GT
Dry-dock hire	$3,835 (2 days)	$5,655 (2.5 days)	$9,000 (3.5 days)
Access equipment	$2,795	$5,070	$17,350
Hull cleaning	$1,885	$2,938	$5,000
Sea-chest cleaning	$650	$650	$1,300
Water charge	$1,885	$1,885	$3,380
Waste removal	$630	$1,261	$1,900
Cost for biofouling removal	$11,674 (1 days)	$17,460 (2 days)	$37,930 (3.5 days)
Additional cost for anti-fouling	$46,150 (3 days)	$73,580 (5 days)	$116,400 (7 days)

Encapsulation

Encapsulation uses an impervious material to wrap a fouled structure in order to reduce the water volume surrounding it, thereby creating toxic conditions that lead to the death of attached biofouling organisms. The wrapping deprives biofouling organisms of light and food while continued respiration and decomposition of organisms within the barrier depletes dissolved oxygen in the water, thereby creating an anoxic environment that is eventually lethal to all enclosed organisms (the "Set-n-forget" method; Coutts & Forrest 2007). The rate of mortality increases with the length of time that the wrap remains intact and in place, but it can take several weeks for all organisms to be killed.

It is possible to accelerate mortality within the wrap by adding freshwater or chemicals to the enclosed seawater (Aquenal Pty Ltd 2007). A range of chemicals has been suggested for this purpose, including acetic acid, sodium hypochlorite, sodium sulphide, or substances that stimulate bacterial decomposition, such as sugar (Clearwater & Hickey 2003, Coutts & Forrest 2005, Morrisey et al. 2009). Any water discharged directly from an encapsulation system will be altered from its natural state and may have unacceptable effects on water and sediment quality in the surrounding environment. Use of biocides within the encapsulation system will require approval from the Environmental Protection Authority (EPA) under Section 31 of the Hazardous Substances and New Organisms Act (HSNO) 1996 if the chemical is hazardous, is used as a biocide or if it has ecotoxic properties in aquatic environments (Subclass 9.1: Aquatic effects). Discharge of waste-water and any harmful substances from the encapsulation system will also require resource consent from the relevant regional authority.

Encapsulation technologies have the potential to reduce biosecurity risk significantly as they are able to contain and kill the biofouling organisms, including mobile species and any larvae or reproductive propagules that they may shed during treatment. However, mortality of all biofouling taxa can take up to 14 days when chemical treatments are not used to accelerate the process (i.e., the set-n-forget method; Inglis et al. 2012). This means that the vessel being treated must remain stationary for an extended period if the treatment is to be effective. Care must also be taken to ensure that organisms are not dislodged when the wrap is deployed and that the wrap does not tear on sharp structures on the vessel or wharf (Inglis et al. 2012). This typically requires deployment in areas of low current and wave energy. To date, the effectiveness of encapsulation has been demonstrated only for vessels <~20m in length (Inglis et al. 2012).

Practical feasibility

In-water cleaning within the coastal marine area of New Zealand may only be carried out if authorised by the relevant regional council. At present, many councils do not allow in-water cleaning or require it to be a consented activity because of the risk of contaminant release from anti-fouling coatings.

Draft guidelines for anti-fouling and in-water cleaning of vessels have recently been released for consultation in New Zealand and Australia (MAF Biosecurity New Zealand 2011). They include a decision support tool designed to assist local authorities with decisions about in-water cleaning practices within their jurisdictions. The guidelines propose that:

- in-water cleaning of micro-fouling (microscopic organisms including bacteria and diatoms and the slimy substances - usually extracellular polysaccharides - that they produce) may be acceptable when:
  - the anti-fouling coating is suitable for cleaning,
  - the cleaning method does not damage the coating surface, and
  - discharges will meet local water quality standards.

- in-water cleaning of macro-fouling (large, distinct multicellular organisms visible to the human eye) may be acceptable when:
  - the organisms are of local origin (i.e., from within the region) and conditions described in the first bullet-point, above can be met, or
  - the organisms are not of local origin, but the cleaning method is able to capture and contain all biofouling waste and described in the first bullet-point, above can be met (MAF Biosecurity New Zealand 2011).

Cost of compliance

The cost for in-water cleaning depends on the size of the vessel, the amount of biofouling present and the methods used (Inglis et al. 2012).

Indicative costs for in-water removal of biofouling from all hull and niche areas using diver controlled brush systems range from NZ$13,600 – $25,200 for a 50 m long ship, plus 1 - 2 days of lost revenue. For vessels up to 100 m length, these costs increase to NZ$27,000 – $40,800 plus 2 - 5 days of lost revenue. Larger vessels, up to 200 m length, will cost NZ$85,000 to $101,000 plus 4 - 5 days of lost revenue (Floerl et al. 2010). Propeller polishing may cost NZ$6,500 to $13,000 depending on the size of vessel (Floerl et al. 2010). Cleaning of sea-chest grates (not involving removal of grate and cleaning of inside of chest) generally ranges from NZ$5,200 to $7,800 (Floerl et al. 2010).

Estimated costs involved in the deployment of an encapsulation system on a 12 m vessel range from NZ$390 to $650, plus up to 10 days laid-up.

For government agencies, there will also be costs of inspection and audit to determine compliance of vessels with standards for cleanliness of the hull and, for regional councils, costs associated with consenting and monitoring in-water cleaning operations.

Expected rate of uptake

As biofouling can accumulate on vessels between dry-dockings and reduce fuel efficiency, some commercial vessels already conduct in-water cleaning of the hull and propellers during the in-service period of the anti-fouling coatings (Takata et al. 2006). Because of the extra costs involved, the willingness of vessel operators to introduce more regular in-water cleaning to their maintenance schedule will depend on the relative importance of the fuel (and speed) penalties imposed by biofouling on their operations and the suitability of the anti-fouling coating to in-water cleaning.

3.10.4 Internal seawater systems

Marine Growth Prevention Systems (MGPS) can be fitted to the internal seawater systems of large commercial vessels to prevent the build-up of biofouling. These mostly use sacrificial anodic copper or chlorine dosing treatments (California State Lands Commission 2012a) and are designed to prevent water flow from being obstructed.

Effectiveness

Although functioning MGPS are recommended in the IMO Biofouling Management Guidelines for commercial vessels (see Section 3.9.1), recent reviews of MGPS by California State Lands Commission (2012a) and Grandison et al. (2012) show that they vary in their effectiveness and are not suited to all operations. Grandison et al. (2012) describe four types of MGPS used by the Royal Australian Navy.

- Sacrificial Anodic Copper Dosing (Cathelco® system).

- Chlorine – as sodium hypochlorite generated on-site (Ecolcell® and Chloropac® hypochlorite generators).
- Copper/Nickel (CuNi) pipework.
- Freshwater flushing.

Although they all have some degree of success at reducing biofouling, their effectiveness varies and depends on how fit-for-purpose the system is to the spaces being treated and how well it is maintained (Grandison et al. 2012). An operating MGPS that is suited to the volume of space it is intended to treat, may be effective at reducing or slowing the build-up of biofouling. Discharges from some MGPS may be regulated as pollutants.

Lewis and Dimas (2007) investigated manual treatment of internal seawater systems using a variety of chemical treatments, the most effective of which were the disinfectants *Conquest* and *Quatsan*, both of which contain the active ingredient benzalkonium chloride. These two treatments caused 100% mortality following immersion for 14 h at concentrations of 1% and above. Other treatments, including vinegar, disinfectants, bleach, de-scalers, commercial pipework treatments and freshwater were less effective (Lewis & Dimas 2007).

The Northern Territory Government uses a dilute disinfectant solution to treat internal seawater systems of recreational vessels entering marinas. The disinfectant is left in the piping for 14 h during which time the on-board water systems cannot be used (Northern Territory Government 2013).

Practical feasibility

There are few data available on the numbers of domestic vessels fitted with MGPS or other systems for treating biofouling in internal spaces. In a survey of 261 international merchant vessels that entered New Zealand between 2007 and 2009, more than half (153 responses) indicated they had some form of treatment system. Most (72%) vessels that indicated they had sea-chests, indicated some form of treatment for biofouling. Responses to this item included electrical systems (63 responses) designed for preventing marine biofouling in pipework and enclosed spaces (i.e., MGPS) and to protect against corrosion (Impressed Current Cathodic Protection Systems (ICCP)) and injection systems using chemical biocides (often Chloropac or Bioguard systems) and hot water (Inglis et al. 2010).

To be effective against some organisms, MGPS that use copper dosing must use levels up to ten times the manufacturer's recommended concentration (10 ppb copper; Grandison et al. 2012). This can greatly increase operational costs and potentially enhance corrosion of seawater piping. Similarly, systems that rely on flushing with freshwater to kill biofouling can require very large volumes of freshwater if the system is run continuously. For many vessels, use of such large volumes of freshwater (particularly from potable supplies) may be cost-prohibitive.

Although there is a range of technologies now available for treating biofouling in internal seawater systems, most are untried on vessels, as they have been developed predominantly for treatment of biofouling in seawater intakes for land-based facilities (Grandison et al. 2012).

Cost of compliance

MGPSs can be installed during new builds or retrofitted to existing vessels when they are in dry-dock. The costs of installation will depend on the size of the vessel and the configuration of its intake and piping systems (Grandison et al. 2012).

3.11 Available practices to reduce risk - dredge spoil and washings

Consents to undertake dredging programmes should require Assessments of the Environmental Effects (AEEs) to consider the potential for introduction or spread of harmful marine organisms by the activity. Applicants should describe the likely presence of any potentially harmful organisms present at dredge and dump sites and should detail how vessels, plant and equipment will be cleaned and managed prior to departure for the proposed works. This should include detail of procedures used to manage biofouling on the vessel (e.g., a Biofouling Management Plan) and to flush sediment, water or other residues from barges and hoppers. Appropriate sampling of current and past spoil grounds and adjacent areas should be required to assess the likely re-distribution and survival of potentially harmful marine organisms from the work area.

Where populations of harmful organisms have been detected at a dredge or dump site, the AEE should address the potential impacts of translocating or re-distributing these species and any mitigation measures necessary.

To reduce the likelihood of translocating a harmful marine organism through dredging activities, it is important when selecting a site to dispose of dredged material to consider the:

- proximity of the loading site to the disposal site (increased proximity between the disposal site and loading site is likely to minimise the risk of transfer of a harmful organism, given that it may be already present at the disposal site),
- similarity of the environment of the loading and disposal sites (including water depth and temperature),
- suitability of the habitat at the disposal site for the survival of harmful marine organisms transferred from the loading site,
- proximity of the disposal site to sensitive areas,
- potentially harmful organisms present at the loading site (if known), and
- potentially harmful organisms present at the disposal site (if known) (Australian Government 2009).

3.12 Assessment of options – dredge spoil and washings

Effectiveness

Incorporating assessment of the potential for transfer of harmful marine organisms into the consenting requirements for dredging programmes would ensure that the risks are considered and mitigation strategies are proposed and implemented.

Feasibility and cost of compliance

This measure would require that proponents of dredging programmes undertake inspections of the dredges before relocation to determine the presence of any potentially harmful organisms and the need for mitigation. Baseline environmental assessments (through desktop study or field survey) of the source and spoil locations will need to determine if harmful organisms are present at the source site that may be spread to the spoil grounds. There will also be costs associated with any mitigation of risk that may be required (e.g., treatment of biofouling or hoppers, using alternate spoil sites material or treating materials sourced from infested locations) and in compliance monitoring by the consenting authority.

Expected rate of uptake

Including consideration of biosecurity risks in consent applications could be implemented relatively easily by consenting authorities, but will involve additional cost to applicants.

3.13 Maritime transport - summary of recommendations

As international shipping lines currently account for more than 85% of the port-to-port movements by large merchant vessels within New Zealand and most visits are of short duration (days) it is important that domestic requirements for marine biosecurity align well with measures being implemented internationally and at the border. When the Ballast Water Management Convention enters into force, all international vessels will be required to meet the D2 discharge standard that has been endorsed by the IMO. Transition to on-board treatment of ballast water is, therefore, expected to be the most effective and practical option for managing domestic movements of ballast water by international shipping in the medium-term. The short port-to-port distances in New Zealand mean that interim measures to reduce risk, involving ballast water exchange or risk-based assessment of discharge are unlikely to be practical or cost-effective. International shipping is also expected to adopt IMO guidelines for managing risk from biofouling and to meet the border requirements for marine biosecurity (the Craft Risk Management Standard) when they enter into force. Both measures require maintenance of an approved Biofouling Management Plan (BMP) that should detail how the vessel manages risks from biofouling during its operations. As there are few facilities in New Zealand capable of cleaning large merchant vessels (in-water or on-shore), management of biofouling is likely to depend on the effectiveness of these international requirements. The short turn-around time for international vessels in New Zealand ports means that they are at relatively low risk of spreading biofouling species domestically if they have been considered low risk at the border.

There is a need for government to work closely with owners and operators of the relatively small fleet of New Zealand-registered merchant vessels to identify practical complementary measures to reduce biosecurity risks. As domestic commercial vessels are already required to undergo regular out-of-water inspections under SSM it should be possible to encourage the fleet to develop and implement a BMP to reduce risks from biofouling. Particular attention to biofouling management is needed for slow-moving commercial vessels or vessels that travel infrequently from port-to-port (e.g., barges, dredges, derelict or decommissioned vessels) since these are likely to constitute the largest risk of spreading biofouling organisms. By requiring resource consents for coastal marine works to consider the potential for transfer of harmful organisms, activities that involve movement of vessels or dredge spoil will be required to specify how they intend to mitigate any risk. To support risk mitigation, more cost-effective options need to be developed within New Zealand for shore-based and in-water cleaning of large vessels.

Research is also needed into lower cost options to manage ballast water on domestic vessels, since the costs of retrofitting ballast treatment systems are likely to be prohibitive for the relatively few vessels involved. There is also a need to establish the risks associated with transport and discharge of bilge water and how existing oil-water separation systems may mitigate that risk. Practical options, such as discharge before moving to a new location or storage of bilge for discharge to waste reception facilities on-shore, should be encouraged in the interim.

4 Mining and exploration pathway

Petroleum (oil and gas) and a wide range of minerals are prospected for and mined within New Zealand (New Zealand Petroleum & Minerals 2011). While over 75% of New Zealand's oil and gas production is obtained from offshore fields (New Zealand Petroleum & Minerals 2013), extraction of minerals from New Zealand's oceans is currently limited to sands and gravel from coastal environments (Centre for Advanced Engineering 2003).

There is considerable potential for future development of the petroleum and mineral resources within New Zealand's Exclusive Economic Zone (EEZ) and Extended Continental Shelf (ECS), much of which are under-explored (MacDiarmid et al. 2012). Advances in technology for prospecting, drilling and production have made commercial extraction of seabed and sub-seafloor resources more viable and there has been significant recent investment in their exploration within New Zealand's oceans. In 2010, for example, around NZ$27 million was spent on minerals prospecting and exploration and around NZ$246 million was spent on petroleum prospecting and exploration (New Zealand Petroleum & Minerals 2011). The oil and gas sector, in particular, is viewed by Government as one of New Zealand's best opportunities for growth in investment. It has placed development of this sector as a high priority in its economic policy (Ministry of Business Innovation and Employment 2012, New Zealand Government 2012).

4.1 Distribution of mining and frontier fields

4.1.1 Petroleum (Oil and Gas)

New Zealand has at least 14 sedimentary basins of various ages with hydrocarbon potential (Figure 4-1). The Taranaki Basin is currently the only province in production within New Zealand, with 16 producing fields. Five of these are in offshore waters: Maui (gas-condensate and oil), Tui Area (oil), Pohokura (gas-condensate), Maari-Manaia (oil), Kupe (gas-condensate). Gas production began at Maui in 1979 and oil has been produced in a separate floating facility since 1996.The Pohukura, Tui, Maari, and Kupe fields have all come on stream since 2006. The Tui and Maari fields collectively contributed 49% of New Zealand's oil production in 2010, while Pohokura contributed a further 22% (New Zealand Petroleum & Minerals 2013). No production wells have been drilled beyond the Taranaki shelf edge and the basin remains under-explored with considerable potential for further discoveries (MacDiarmid et al. 2012).

Petroleum exploration permits are allocated by Government through an annual round of competitive tenders ("block offers"). Since 2005, block offers for exploration have been released for the East Coast Basin, parts of the offshore and onshore Taranaki Basin, Great South Basin, Reinga Basin, Northland Basin and the Raukumara Basin. Three offshore blocks were offered for tender in 2013. These are located within the Taranaki Basin, and the Reinga-Northland and Great South-Canterbury Provinces.

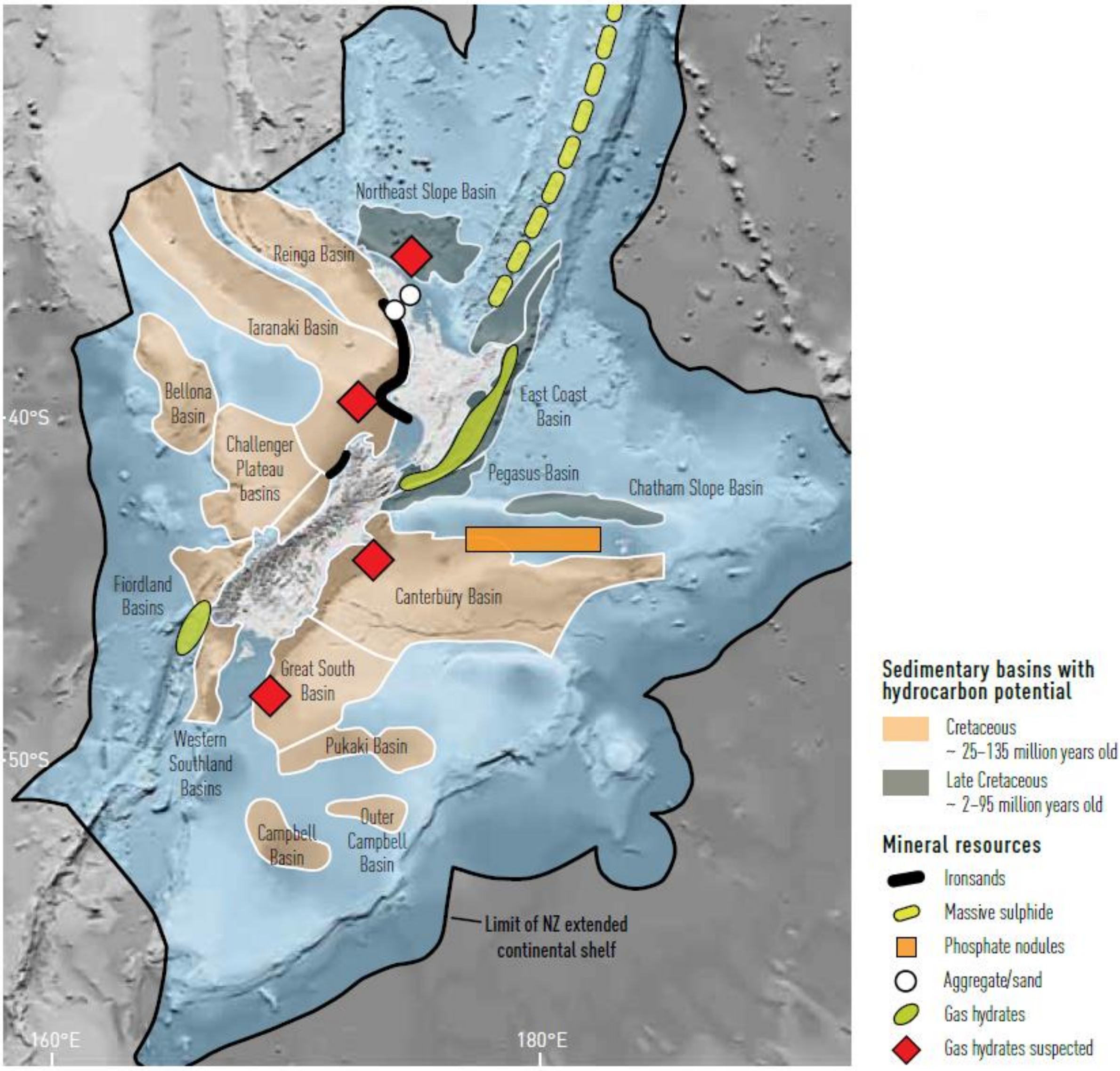

Figure 4-1 Prospective basins with hydrocarbon potential and the distribution of known mineral deposits within New Zealand's Extended Continental Shelf (Source: MacDiarmid et al. 2012).

4.1.2 Gas hydrates

Gas hydrates are crystalline solids consisting of gas molecules, usually methane, surrounded by a cage of water molecules. They form where gas is present in the moderate pressures and low temperatures in the first few hundred metres beneath the seafloor of deep-water basins. New Zealand has one of the largest single offshore gas hydrate provinces in the world, along the east coast of the North Island (Hikurangi Margin) and the south-west coast of the South Island (Fiordland Margin) (MacDiarmid et al. 2012, Robinson 2011). Other deposits are suspected in at least four areas (Figure 4-1).

Despite their potential, there is no commercial production from gas hydrates anywhere in the world. Exploitation remains challenging because the volume of gas expands greatly when it is brought to the surface. Drilling infrastructure used to extract gas hydrates, such as rigs, production platforms and pipelines, must be capable of resisting extreme environmental and pressure conditions. At present these systems are only in experimental development in Japan and the USA (Centre for Advanced Engineering 2003).

4.1.3 Minerals

Most of New Zealand's current mining for minerals occurs onshore, but there is some, limited extraction of coastal and marine deposits.

Sand and aggregates

Extraction of marine sands and aggregate for the construction industry occurs in the Kaipara Harbour and at Mangawhai Heads in Northland. Since the early 1990s commercial operators have suction-dredged sand from the sandbars off Mangawhai Heads and Pākiri Beach (north of Cape Rodney), extracting 165,000 m^3 per year over 10 years (Wright 2007). The Auckland region sees the most coastal extraction; over 350,000 m^3 is taken each year from east coast beaches and the entrance to Kaipara Harbour. Shallow, coastal dredging operations for sand and aggregate are expected to increase as demand from the construction industry increases and as mining on land becomes more contentious (Centre for Advanced Engineering 2003).

Quartz-rich silica sands have been dredged from Parengarenga Harbour and around Kaipara Harbour in the past and barged to Auckland and Whangarei for processing into glass. Glass production at the Whangarei plant ceased in 1991 and dredging in Parengarenga stopped in 1997 (Christie & Barker 2007).

Ironsands

Iron sand is a general term for sand-sized grains of iron-rich minerals, principally magnetite (Fe_3O_4), titanomagnetite (Fe_2TiO_3), and ilmenite ($FeTiO_3$). Titanomagnetite deposits are distributed along 450 km of coastline between Whanganui and Kaipara Harbour (Figure 4-1). They are currently mined for export and for domestic steel production at two sites, Waikato North Head and Taharoa, with a combined production of 2,357,460 t in 2011. Deposits at these sites are coastal rather than oceanic. Mining is conducted with suction pipes, pumping sand mixed with seawater from the seabed. Iron ore is magnetically separated from the sand, whilst other minerals are extracted by sieving, before returning the residue back to the sea. Concentrate mined at Waikato North Head is piped as a slurry to the Glenbrook Steel mill. At Taharoa, iron sand concentrate is slurried through a pipeline to an offshore loading facility for export.

Ilmenite-rich black sands, with locally economic concentrations of gold, are present at intervals along 320 km of the west coast of the South Island. The largest deposits are at Barrytown (6.9 Mt of ilmenite) and near Westport (5.5 Mt of ilmenite) (MacDiarmid et al. 2012).

Phosphorite nodules (Rock phosphate)

Phosphorite nodules are patchily distributed in water depths of about 400 m on the crest of the Chatham Rise. Commercial extraction of rock phosphates from this resource has been proposed for use in fertilisers, with glauconite as a by-product (Castle 2013). A prospecting licence was issued in 2010 for 4,726 km^2 on the Chatham Rise. Investigations undertaken between 2011 and 2012 suggest that commercial extraction is viable and an application for a licence to mine was made in September 2012 (Castle 2013). Mining is proposed to use a modified trailing suction hopper dredge that would travel to and from the mainland (Schoute 2013).

Placer gold

Alluvial deposits ("placers") are found on beaches of the west and south coasts of the South Island. Offshore deposits of placer gold occur off the Coromandel Peninsula and Hokitika. Exploration permits are held for the coast off the Westland Continental Shelf, between Karamea and Jackson's Head. While some exploration of these resources has taken place, the gold is difficult to recover with existing technology (Centre for Advanced Engineering 2003).

Platinum Group Metals

Platinum Group Metals include platinum (Pt), palladium (Pd), iridium (Ir), rhodium (Rh), osmium (Os) and ruthenium (Ru). They are typically used as catalysts in the automotive, chemical and petroleum refining industries and as corrosion resistant materials in the chemical, electrical, glass and medical and dental industries. The PGM deposits with greatest historic importance and some future potential in New Zealand are the placer deposits of Southland. PGM-bearing sands extend continuously eastward along the beaches at Orepuki and along the beaches and raised beaches at Waipapa, Twelvemile and Otara, a distance of about 100 km.

Polymetallic nodules

Polymetalic nodules (also known as manganese nodules) are sea floor concretions that contain varying amounts of manganese, iron, cobalt, copper and nickel. They may also contain small quantities of gold, silver, platinum, molybdenum and zinc (Centre for Advanced Engineering 2003). In New Zealand, polymetallic nodules occur over a very large area (~25,0000 km^2) in deep water (4,000-5,000 m) immediately southeast of the Campbell Plateau and in the vicinity of Bollon's Seamount (MacDiarmid et al. 2012). Extraction techniques from these depths are likely to involve a seafloor hydraulic suction dredge connected to a mining platform via a flexible hose and rigid pipe string for transporting the nodules from the seafloor to the sea surface (International Seabed Authority 2008).

Massive sulphides

There is increasing commercial interest in mining Seafloor Massive Sulphides (SMS), which form in submarine volcanic regions where sulphur-rich magmatic and hydrothermal fluids precipitate sulphur and metals around hydrothermal vents (MacDiarmid et al. 2012). SMS deposits can contain economically viable reserves of iron, copper, lead and zinc, with some also rich in gold and silver (Hoagland et al. 2010).

In the New Zealand EEZ and ECS hydrothermal venting is known to occur on two-thirds of the ~30 Kermadec Arc volcanoes (de Ronde et al. 2007), but only two sites, Brothers and Rumble II West, are so far known to have SMS deposits. Deposits may also occur elsewhere in the Kermadec Arc – Havre Trough volcanic system (MacDiarmid et al. 2012).

Technology for extracting polymetallic sulfides from the seafloor has not been fully developed. Plans to mine SMS overseas propose using large, remotely-controlled hydraulic grabs or continuous mining systems with cutter heads that crush the ore on the seabed, lift it hydraulically to a surface vessel, dewater it, and pump the fluid back to the seafloor (Hoagland et al. 2010).

4.2 Mining life cycle & potential vectors

Offshore exploration and production involves a range of commercial vessel types and equipment that is used at different stages of the development life-cycle. Offshore field development incorporates five generic stages, each of which can have associated biosecurity risks (IPIECA & International Association of Oil & Gas Producers 2010):

4.2.1 Exploration phase

During the initial exploratory phase, prospecting typically involves acquisition of data about the location of the resource and its potential. This can include acoustic bathymetric and seismic surveys and exploratory/appraisal drilling or collection of samples.

Exploration/appraisal drilling or collection of samples is undertaken to confirm the presence of the resource and to define its size and distribution. For petroleum exploration, drilling in deeper water is done using a semi-submersible rig or drill ship that is anchored over the drill site. In shallower waters, 'jack-up' rigs may be used (IPIECA & International Association of Oil & Gas Producers 2010). To determine the extent of the resource, the drill rig may be moved to a number of sites within each field. These drill rigs, collectively referred to as Mobile Offshore Drilling Units (MODUs) are in high demand internationally, with daily charter rates of US$400,000 or more [6]. Drill ships will travel into and around New Zealand under their own steam, but semi-submersible and jack-up rigs will typically be wet-towed by tugs or transported by a heavy-lift ship. Because of the costs of mobilising MODUs to New Zealand, the rig may be used to drill within a number of fields and basins while it is present in our EEZ. Supply vessels are used to transport supplies, equipment and crew between the drilling rig and onshore facilities (IPIECA & International Association of Oil & Gas Producers 2010).

Collection of samples from mineral resources located at, or near, the seabed surface will typically be done from specially equipped ships rather than from drill or coring platforms (MacDiarmid et al. 2012).This may include use of short cores, grabs, dredges, and camera systems (towed or remotely operated).

Baseline environmental assessments of the field may also be done at this stage, utilising many of the same sorts of equipment for obtaining samples of the seafloor surface.

4.2.2 Field development

During development of petroleum fields, production wells are drilled and supporting infrastructure and facilities are constructed. Production platforms may be purpose built in New Zealand or transported in from overseas. Equipment, materials and supplies for drilling operations will be transported to the site by supply vessels. Construction may require use of barges, vessels with lifting or pipe-laying capability and dive vessels. Offshore fields can require the installation of flowlines and sub-sea development systems. In some areas, floating production storage and offloading (FPSO) vessels are used. These are anchored in position, but can be moved among sites (IPIECA & International Association of Oil & Gas Producers 2010).

4.2.3 Field production

A number of production wells may be drilled on petroleum fields. These may be associated with fixed platforms or a surface mooring for transfer of oil or gas to a FSPO or tanker. During the production phase, vessels will transport materials, equipment, supplies and people to and from production vessels or platforms, although this will be at a smaller scale than during development of the field.

The vessels and equipment used in the production phase for mineral extraction will vary depending on the type of resource and its depth and location. Extraction may utilise dredges of different types (mechanical or hydraulic), hopper barges, tugs, supply vessels and anchoring and mooring systems.

4.2.4 Product Transport

Transport of petroleum products from the field is done through pipelines laid to shore-based facilities or using tankers or FSPOs.

Minerals may be transported to shore based facilities by the dredge itself (e.g., trailing suction hopper dredge) or by barges. Refined or concentrated product may be transported to market in bulk carriers.

4.2.5 Decommissioning and remediation

At the end of an oil and gas field's life, the wells are plugged and the production facilities and associated structures are removed. As in the development phase, this will involve use of a range of other vessels to transport materials to and from the site being decommissioned. Removal and disposal of large platforms is expensive and, in some instances overseas,

[6] Rigzone - http://www.rigzone.com/data/dayrates/

where the platform has no future use, they have been towed to other sites and sunk for use as artificial reefs.

Decommissioning of mineral fields is likely to be part of on-going production, as equipment is moved around the field once ore-bearing material in one part has been exhausted (MacDiarmid et al. 2012).

4.3 Modes of infection

Table 4-1 presents a summary of potential vectors and modes of infection for the transport of harmful marine organisms during different stages of the mining life cycle. Marine species can be transported:

- as biofouling attached to wetted surfaces of vessels, MODUs and platforms,
- as biofouling attached to equipment that is immersed in seawater for extended periods(e.g., anchor arrays, spud cans, chains, moorings, pipelines, etc.),
- through uptake in ballast water used to control the stability of large vessels (e.g., heavy-lift ships, semi-submersible rigs, tankers, bulk carriers),
- through uptake in seawater used for other ship-board operations (e.g., bilges, cooling water, holding tanks, etc.),
- through uptake in seawater used to slurry dredged material,
- as contaminants picked up unintentionally during deployment and retrieval of maritime equipment (e.g., seismic streamers, side-scan sonar, magnetometers, anchors, chains, mooring ropes, ROVs, etc.), and
- as contaminants picked up unintentionally in material removed from the seabed (e.g., dredged material, corers, traps, ROVs, benthic sleds, etc.).

The risks of domestic transport of harmful marine organisms will depend on the origin of biofouling, ballast or bilge water, and hitch-hiker species that are entrained within these vectors. For example, seawater taken on-board in the open ocean (>50 nm from the coast or in waters >200 m deep) may contain relatively few harmful coastal organisms and, therefore, may represent a lower risk than water taken on-board within the territorial sea. Similarly, most organisms picked up unintentionally from the seafloor of the deep ocean, will be unable to survive in shallow, coastal environments.

Table 4-1. Summary of potential vectors and modes of infection for the spread of harmful marine organisms at different stages in the mining life cycle. (Adapted from IPIECA and International Association of Oil & Gas Producers, 2010).

Phase	Activity	Potential Vectors	Modes of infection
Exploration	Seismic and environmental surveys	Survey vessels Ocean bottom survey equipment Seismic survey equipment	Biofouling Bilge water Contaminants (sediment and water)
	Exploration & appraisal drilling	Drilling rig / ship Heavy-lift ship or tugs for transport of MODUs Anchoring equipment Constructed / artificial islands Service & supply vessels	Biofouling Bilge water Contaminants (sediment and water) Ballast water
Field development	Development drilling Installation of infrastructure	Production platform or drilling rig Heavy-lift ship or tugs for transport of platform Anchoring equipment Pipelines & umbilicals Sub-sea Xmas tree Service & supply vessels Dive equipment	Ballast water Biofouling Bilge Contaminants (sediment and water)
Production	Operation of infrastructure	Production platforms FSPOs Dredges Barges Tugs Service & Supply vessels Dive equipment	Ballast water Biofouling Bilge Contaminants (sediment and water)
Product transport	Operation of infrastructure	Sub-sea pipelines	N/A
		Shuttle tankers Gas carriers FSPOs Barges Hopper dredges Bulk carriers	Biofouling Ballast water Bilge Contaminants (sediment and water)
Decommissioning and remediation		Service & Supply vessels Transport & disposal of decommissioned structures (e.g., platforms, pipelines) Dive equipment	Biofouling Bilge Contaminants (sediment and water)

4.3.1 Vessels

The offshore mining sector uses a range of vessel types and infrastructure during different stages of field development (Table 4-2). Many of these are highly specialised (e.g., seismic survey vessels, pipe-laying vessels, MODUs, drill ships, FSPOs, deep water dredges, etc.) with a limited number in-service worldwide under high demand (IPIECA & International Association of Oil & Gas Producers 2010).

Like other commercial vessels (Section 3.1), vessels used in the mining sector will develop biofouling on their submerged surfaces and transport seawater bilge and internal water spaces (Section 3.4.2). Large vessels used within the industry, such as heavy-lift ships, semi-submersibles, FPSOs, and tankers, will also transport significant quantities of ballast water.

MODUs, FPSOs, and production platforms associated with offshore exploration and mining represent a different category of biofouling risk from merchant shipping. Because they are stationary for long periods, these structures can develop a much greater mass of biofouling and harbour many more species and individuals than a ship (Lewbel et al. 1987, Stachowitsch et al. 2002, Yeo et al. 2009). MODU's are moved from one field to another or between oceans on heavy-lift vessels or they are towed by tugs ('wet-tow'). Wet-tows occur at relatively slow speeds so MODUs can also transport significant numbers of larger, mobile species such as crabs and small fishes and have been likened to moving reefs (Yeo et al. 2009).

4.3.2 Immersible equipment

The sector also deploys a range of equipment at different stages of exploration and production (Table 4-1, Table 4-2). Equipment deployed for extended periods (e.g., anchor arrays, pipelines, spud cans, etc.) can become fouled by marine organisms. Equipment with shorter deployments (e.g., seismic streamers, sampling equipment, etc.) may entrain seawater, entangle floating organisms or, if used on the seafloor, pick up benthic organisms.

Table 4-2. Summary of vessels and equipment used in offshore petroleum and mineral fields (Adapted from IPIECA and International Association of Oil & Gas Producers, 2010).

Vessels	Immersible equipment
Mobile Offshore Drilling Units (MODUs) – including jack-up rigs, drill ships and semi-submersible rigs	Remotely-operated vehicles (ROVs)
Offshore support vessels	Production jackets
Crew transfer vessels	Concrete gravity structures (CSG)
Diving support vessels	Seabed anchor arrays
Accommodation vessels	Subsea equipment – (e.g., spud cans, pipelines)
Seismic survey vessels	Riser turret moorings and single anchor leg rigid arm moorings
Landing craft	Sampling equipment (e.g., corers, grabs, benthic sleds, etc.)
Pipelaying vessels	Survey equipment (e.g., seismic streamers, side scan sonar, multi-beam echo sounders, magnetometers, sparkers, boomers)
Floating Production, Storage and Offloading vessels (FPSOs) and Floating Storage and Offloading vessels (FSOs)	Anchors, chains, ropes,etc.
Controlled Source Electromagnetic Vessels (CSEVs)	
Dredges (Mechanical, Hydraulic, etc.)	
Barges	
Tugs	

4.4 Best-practice to reduce risk

International best-practice in the offshore oil and gas industry is now to consider risks from harmful marine organisms at an early stage of project planning and to build mitigation strategies into the overall Environmental Management Plan (EMP) (IPIECA & International Association of Oil & Gas Producers 2010). This allows risks to be considered not just for individual craft, but across all vessels and stages of the operations, including contracting and transport of craft from overseas, onshore-offshore movement of service vessels and equipment, relocation between domestic fields and decommissioning prior to relocation outside New Zealand. The EMP should incorporate steps taken to identify biosecurity risks (e.g., audit of existing BMPs and inspections prior to arrival, relocation and departure), to assess the likelihood of adverse consequences, and to mitigate them (e.g., cleaning & transportation methods) for each project activity.

The global oil and gas industry association for environmental and social issues (IPIECA) and the International Association of Oil & Gas Producers make three generic recommendations to reduce the risk of transporting harmful marine organisms (IPIECA & International Association of Oil & Gas Producers 2010.).

- Consult national and local legislation at the destination before departure from home port.
- Source vessels locally where possible.
- Consider the use of vessels with anti-AIS (Alien Invasive Species) treatment capability, if available.

More specific recommendations made by IPIECA for managing risks from ballast water and biofouling are presented below.

A *Craft Risk Management Standard* (CRMS) is currently under development to manage marine biosecurity risks on all vessels entering New Zealand waters from overseas (see Section 3.9.2). The standard will align with, and encourage shipping to adopt, the IMO Guidelines for Vessel Biofouling (see Sections 3.9.1 and 3.9.2). The CRMS will make some requirements for craft arriving into the EEZ in future, but until regulations are promulgated for this under the new Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012, 'arrival or entry into New Zealand' will mean arrival into the territorial sea or internal waters of New Zealand." So the CRMS will extend to the EEZ but enforcement will not until the EEZ regulations are in place. Nevertheless, MPI is encouraging all vessels to take reasonable steps to deal with biofouling or prevent de-fouling activities occurring in New Zealand's jurisdictional area.

4.5 Available practices to reduce risk – ballast and bilge water

The IPIECA specifically recommends the following practices within the offshore oil and gas industry to minimise the risk of transporting harmful marine organisms in ballast water.

- All vessels containing ballast water should carry a vessel-specific Ballast Water Management Plan (BWMP) and Log.
- Avoid taking on ballast water in areas where there is high potential for the presence of harmful organisms (e.g., coastal waters).
- Manage ballast to minimise or remove the need for discharge.
- Use appropriate onshore discharge, where possible.

- Discharge only ballast water considered to be ‘low risk’ in port/inshore waters (e.g., ballast taken on >200 nm from land).
- Treat ballast sediment as having a high potential for containing harmful organisms.
- Dispose of ballast sediment safely onshore or in mid-ocean water of at least 200 m depth.
- Ballast exchange should, as far as practicable, be conducted in deep water (at least 200 m) and as far as possible from land.

4.6 Assessment of options – ballast and bilge water

In general, the measures and considerations described in Sections 3.6, and 3.8 for treatment of ballast water and bilge on commercial vessels will also apply to vessels used in the mining sector.

4.7 Available practices to reduce risk – Biofouling

The IPIECA recommends the following practices within the offshore oil and gas industry to minimise the risk of transporting harmful marine organisms in biofouling.

- Maintain a Biofouling Management Plan and Log for all vessels.
- Where possible, remove biofouling:
  - in the area of its origin,
  - before deployment to a new area,
  - in a way that does not further transmit harmful marine organisms.
- Use anti-fouling paints that comply with the International Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS Convention) and national legislation.
- Ensure that the selected paint is suitable for the specific application required.
- Undertake maintenance to ensure integrity of paint coverage.
- Treat small vessels as potentially significant pathways for transmitting harmful marine organisms.
- Use careful cleaning and inspection to minimise transmission of harmful marine organisms.

Additional guidance for mitigating biofouling risk is provided by the Commonwealth of Australia (2009c).

4.8 Assessment of options – biofouling

Feasibility, costs of compliance and likely uptake

Because of the size of vessels used in the offshore industry and the high costs involved in their charter and operation, the range of practical solutions for managing biofouling risks within New Zealand is much reduced compared to the maritime transport sector. Because of their size, there are relatively few options available to remove harmful biofouling organisms from MODUs, production platforms, drill ships and other large vessels used in the petroleum industry (Hopkins & Forrest 2010). Greatest mitigation of biofouling risk is achieved by dry-docking and cleaning, but this is not practical or cost-effective for domestic movements of these large craft. Dry-docks have advance bookings of many months and the closest facilities to New Zealand capable of handling a MODU are in Singapore, requiring significant delay, re-routing of the rigs and very considerable additional expense. For example, Aquenal Pty Ltd (2009) gave indicative costs for cleaning a MODU in dry-dock in Singapore at ~NZ$10 million over a 10 day period. Charter costs for transport to and from dry-dock were ~NZ$650,000 per day for a wet-tow and NZ$600,000 per day plus mobilisation costs of NZ$100,000 for a heavy lift ship.

De-fouling can sometimes be done in situ, using high pressure water-blasters or brush systems, but this is hazardous, must be done in sheltered waters and comes with the associated risks of potential release of harmful organisms or toxic residues from anti-fouling coatings into the surrounding environment. Up to 30 days may be required to clean a semi-submersible thoroughly using high pressure water-blasting, with an indicative cost of ~NZ$1 million (Aquenal Pty Ltd 2009). This does not include any opportunity costs incurred by having the vessel stationary in sheltered waters for this extended period of time.

Transport of MODUs by heavy lift ship is preferable to wet-tow because it provides an opportunity for cleaning of the structures in-transit (e.g., by water-blasting) and, on long voyages, can result in the death of biofouling organisms through desiccation. However, because the rate at which biofouling organisms die when exposed to air varies considerably, up to 21 days of exposure may be required for desiccation to be effective (Inglis et al. 2012). From a practical point of view, the costs of mobilising and chartering a heavy lift ship to travel to New Zealand in order to move the MODU between domestic basins or fields may preclude these options.

Encapsulation has also been suggested as a method for treating biofouling on MODUs (Aquenal Pty Ltd 2009), but there have been no tests of its efficacy for these structures.

In-water inspections of the biofouling prior to movement may be able to determine if any harmful organisms are present and, therefore, whether any direct mitigation is required. Screening inspections can be carried out successfully using Remotely Operated Vehicles (ROVs) or divers (Floerl & Coutts 2011). Inspections should be undertaken by suitably qualified and experienced personnel familiar with biofouling and harmful marine organisms. Robust inspections require good survey design to ensure that the inspection adequately describes the species present and can detect potentially harmful organisms with high confidence. They must be underpinned by taxonomic expertise capable of identifying potentially harmful species.

Decommissioning, removal or abandonment of a floating or production platform should be preceded by an appraisal of biosecurity risk (Commonwealth of Australia 2009c). This should be covered in the Environmental Management Plan for the project life cycle. Proposals to dispose of derelict vessels or structures at sea will require a dumping permit from Maritime New Zealand under the Maritime Transport Act 1994. Applicants must demonstrate that material capable of contributing to “pollution of the marine environment has been removed to the maximum extent”.

4.9 Available practices to reduce risk – biofouling and contamination of immersible equipment

High pressure washing, with freshwater or seawater, of equipment deployed for extended periods is the simplest way of removing accumulated biofouling from anchors, cables and other large marine equipment that is deployed for extended periods (Commonwealth of Australia 2009c). Risks from survey and sampling equipment deployed for shorter periods of time may be mitigated by routine washing with freshwater and drying or by soaking in hot water and detergent (Commonwealth of Australia 2009c). A summary of recommended approaches for washing, rinsing or drying marine equipment to reduce the risk of transporting harmful marine organisms is provided in Table 4-3.

4.10 Assessment of options – biofouling and contamination of immersible equipment

Effectiveness

High pressure water-blasting would typically be done on-board support vessels or in shore-based facilities and is the most effective measure for removing biofouling from large items of equipment. Water-blasting is less effective for complex structures that contain fouled recesses or internalt spaces. Care should also be taken to ensure that washings and biofouling waste are disposed of appropriately, as some organisms or their offspring will survive the cleaning process. Where the equipment is cleaned at the site of origin of the biofouling, then returning the wastes to the sea may pose minimal biosecurity risk. Where possible, however, the recommended practice is to retain the waste for disposal to landfill on shore.

Soaking in freshwater, hot water or detergents is most suited to smaller items of deployed equipment that have not been heavily fouled (e.g., ropes, anchors, transducers, etc.). The effectiveness of the treatment will depend on the level of fouling, the duration over which the equipment was soaked and the type of disinfectant or detergent used to kill any associated organisms (Table 4-3).

Feasibility, cost and rate of uptake

In general, the measures recommended for cleaning immersible equipment are readily available and low cost to implement for most types of equipment. Uptake is unlikely to be limited by the cost of implementation except in cases where the equipment is very large and cannot be removed easily from the water. The sector and individual companies should be encouraged to incorporate the simple measures for de-contamination into their standard operating procedures.

4.11 Mining and exploration pathway – summary of recommendations

The mining and exploration sector uses a range of different types of vessels and equipment at different stages during the development and operation of a field that may potentially spread harmful marine organisms. The sector should be encouraged to adopt international best practice by:

- evaluating risks from harmful marine organisms at an early stage of project planning, and
- building mitigation strategies into the overall Environmental Management Plan (EMP) for the life-cycle of the project.

The EMP should include development and implementation of ballast water and biofouling risk management plans for all vessels and large mobile equipment, and Standard Operating Procedures for wash-down and, if necessary, sterilisation of immersed equipment before movement to a new location. For large vessels operating on offshore projects, ballast water exchange may be a practical option prior to moving between fields. There are no practical options for removing biofouling from large MODUs, drill ships and dredges that are already present in New Zealand. Plans to relocate these facilities within New Zealand should evaluate biosecurity risks in the EMP and develop appropriate strategies to mitigate any risks. These may include:

- cleaning and anti-fouling of the vessel prior to its arrival in New Zealand,
- inspection and evaluation of biofouling prior to relocation,

- appropriate choice of methods for relocation (e.g., heavy-lift ship) or route of movement between fields (e.g., at a safe distance from coastal areas).

Table 4-3. Options recommended for treating marine equipment to prevent the spread of harmful marine organisms. (Source: Dunmore et al. 2011).

Soak	Spray/wash	Dry
Soak the item/s using one of the methods below. ▪ Freshwater for at least 72 h. If soaking ropes, freshwater should be replaced after 12 h. ▪ Hot water (>40°C) for 20 min. Temperatures exceeding 48 °C should not be used on dive equipment as certain temperature-sensitive gear may be damaged. ▪ 5% Palmolive® dishwashing detergent/freshwater solution for 60 min. ▪ 1% Dettol® antiseptic/ freshwater solution for 60 min. ▪ 2% bleach/freshwater solution for 30 min.* ▪ 2% Decon 90®/freshwater solution for 30 min. ▪ 5% acetic acid/ freshwater solution OR undiluted household vinegar for 10 min*.	For items too large or difficult to soak, spray the item/s using one of the methods below. ▪ 1% Dettol® antiseptic/ freshwater solution and leave for 60 min. ▪ 5% acetic acid/ freshwater solution OR undiluted household vinegar and leave for 10 min. ▪ When spraying an item, ensure you generously cover all surfaces.	For an item where chemical/ freshwater treatment is not feasible, remove from water and thoroughly air dry for 1 month. Care is needed to ensure that the item is laid out in a manner that ensures all surfaces are completely dried. Prolonged air exposure is also an ideal complementary treatment for any item/s that has been soaked or sprayed.

* Not recommended for dive gear as it may compromise the integrity of some plastics

5 Commercial fishing pathway

New Zealand's domestic fishing industry currently contributes around NZ$1.5b to the economy each year (Ministerial Inquiry Panel 2012). For planning and management purposes, the marine fishery is divided into four sectors: (1) inshore finfish, (2) inshore shellfish and seaweed, (3) deep-water and middle-depth, and (4) highly migratory species. There are over 1,500 commercial fishing vessels registered in New Zealand and 239 licensed fish receivers and processors (Ministry for Primary Industries 2012a).

5.1 Inshore fisheries

5.1.1 Finfish

Although not formally defined, inshore fisheries are typically those that occur between the landward boundary of mean high water springs and either the limit of the territorial s ea (12 nm) or the 200 m water depth contour. Approximately 40 different inshore finfish species are managed within New Zealand's Quota Management System (QMS), comprising 200 individual stocks. Important fisheries include snapper, blue cod, bluenose, tarakihi, warehou, gurnard, rig, blue moki, flounder, hapuka (groper), trevally, turbot, school shark and john dory.

The inshore fleet comprises both independent fishers contracted to larger quota owning companies and small owner-operators. Vessels within the fisheries are mostly between 5 and 20 m in length (Ministry of Fisheries 2011c). The fleet is located throughout New Zealand and the Chatham Islands, with main ports being Bluff, Kaikoura, Lyttelton, Nelson, Riverton and Timaru in the South Island and Tauranga, Auckland, Wellington, Napier and Gisborne in the North Island (Ministry of Fisheries 2011c). The fishery uses a range of methods, including trawling, set netting, potting, trolling, purse seining and line fishing.

5.1.2 Shellfish and seaweed

Twenty-four shellfish species are managed within the QMS, comprising 201 individual stocks (Ministry of Fisheries 2011c). About 5,000 species are also managed outside the QMS. Important inshore shellfish species include rock lobsters, paua, scallops, and oysters. Fisheries for seaweed include a generic beach-cast seaweed fishery and small fisheries for *Pterocladia* spp. (comb weed), *Macrocystis pyrifera* (bladder kelp) and *Porphyra* spp. (karengo)(Ministry of Fisheries 2011c). Commercial harvesting and farming of the Asian kelp, *Undaria pinnatifida*, is allowed under controlled circumstances (Office of the Minister for Biosecurity 2010).

Many shellfish and seaweeds are commercially harvested from shore or from tenders. Larger vessels are employed for the rock lobster, oyster, scallop and queen scallop fisheries. The main methods used for commercial harvesting are potting (for rock lobster and paddle crab), dredging (for scallops and dredge oysters), body dredging (for cockles) and hand-gathering by free-diving (for paua and kina) (Ministry of Fisheries 2011c). Hydraulic dredging is used for the harvest of surf-clams.

5.2 Deep-water and middle-depth fisheries

Deep-water and middle-depth fisheries are generally understood to be those that occur mainly in waters deeper than 200 m and between the territorial sea and the limit of the Exclusive Economic Zone (EEZ). More than 30 species of finfish and invertebrate are managed under QMS in the deep-water fishery (Ministerial Inquiry Panel 2012), with major species including squid (main season December to May), hoki (June to September), ling (year-round), oreo dories (year-round), orange roughy (May to August), and silver warehou (year-round).

The deep-water fleet consists of a mixture of trawl and long-line vessels, domestic and foreign chartered vessels (FCVs) and factory trawler and fresher vessels. FCVs may be New

Zealand flagged under charter agreements (Section 2 of the Ship Registration Act 1992), but this is unusual. Most are foreign flagged and registered. FCVs are restricted to operating in the Exclusive Economic Zone (EEZ), and account for over half the fisheries catch (Ministerial Inquiry Panel 2012). The Ministry for Primary Industries has proposed a number of changes to fisheries regulations to give effect to decisions relating to the Foreign Charter Vessel review (Ministerial Inquiry Panel 2012). Among these is a draft recommendation that all foreign-flagged fishing vessels intending to fish in New Zealand's fisheries waters will be required to reflag to New Zealand by May 2016. This will ensure jurisdictional clarity and enable consistent enforcement of New Zealand laws across all commercial fishing vessels operating in New Zealand waters (Ministry for Primary Industries 2013).

In the 2010/11 fishing year, there were 56 vessels operating in New Zealand's deep-water and pelagic EEZ fisheries. Twenty seven of these vessels were FCVs and 29 were domestic vessels. Six of these FCVs were seasonal vessels, in fisheries such as the squid jig and tuna long-line fisheries that require specialist gear or particular vessel capabilities. The FCVs that remain in the EEZ year round are all trawl vessels, apart from one that pots for hagfish (Ministerial Inquiry Panel 2012). Most fishing activity in the EEZ is undertaken by trawl vessels using a combination of bottom and mid-water trawl nets. A long-line fleet fishes for ling and there is a developing pot fishery for deep-water crabs (Ministry of Fisheries 2011a).

5.3 Highly migratory species

Highly migratory species are specifically defined in Annex 1 of the United Nations Convention on the Law of the Sea and in Schedule 4B of the Fisheries Act 1996. They are typically large pelagic species whose stocks span the Territorial Seas and EEZs of multiple countries and the high seas. They include surface long-line fisheries for southern bluefin tuna, bigeye and swordfish, and recreational fisheries for marlins, swordfish, and large tunas. Commercial purse seine fisheries for skipjack tuna occur within New Zealand fisheries waters and in the western and central Pacific (on the high seas and by agreement in other countries' zones). Commercial troll fisheries for albacore tuna occur within New Zealand fisheries waters. Elsewhere in the Pacific, and to some extent in New Zealand, albacore is also the target of long-line fisheries (Ministry of Fisheries 2011b).

Around 170 domestically owned and operated vessels (mostly 15 to 25 m length) make up the main part of the domestic commercial New Zealand tuna fishing fleet. These vessels use troll or long-line gear, and may operate for part of the year in non-tuna fisheries. Surface long-line vessels target multiple species including tuna and swordfish.

Four New Zealand-flagged Class-6 purse seiners (vessels with over 4,256 t combined hold capacity) fish in New Zealand waters for skip-jack tuna and in the Pacific high seas and EEZs of some Pacific Island states. Around 10 smaller purse-seiners fish domestically within New Zealand

The long-line fishery for southern bluefin and bigeye tuna is seasonal and occurs mostly off the east coast of the North Island and the west coast of the South Island. The albacore troll fishery is based mainly on the west coast of the North and South Islands. The purse seine fishery within New Zealand waters occurs on both the east and west coast of the North Island between January and May (Ministry of Fisheries 2011b).

Table 5-1. Summary of commercial fishing activities in New Zealand (Source: Seafood New Zealand).

Fisheries group	Depth	Fishing method	Fish caught
Crustaceans and shellfish	Inshore waters	Dredging, potting and diving	Spiny rock lobster (crayfish), paua, scallops, oysters, clams, cockles, and crab from shallow inshore waters, and scampi and queen scallops from deeper water.
Inshore fisheries	Near shore up to 200 metres	Trawling, set netting and bottom longlining	Snapper, red cod, bluenose, monkfish, tarakihi, warehou, gurnard, trevally, rig, blue moki, flounder, groper, turbot, and john dory.
Pelagic fisheries	Surface waters to 200 metres	Purse seining, mid-water trawl, ocean trolling, and surface longlining	Tuna, mackerel, barracouta, and kahawai.
Middle-depth fisheries	200-600 metres	Trawling, bottom longlining and jigging	Hoki, squid, hake, ling, barracouta, and warehou.
Deep-water fisheries	600-1,000 metres	Trawling with specialised gear	Orange roughy, cardinal, alfonsino and oreo dory.

5.4 Domestic movements of fishing vessels

Fishing vessels spend varying amounts of time in port depending on their size, and operations. Reasons for entering port can include the need to unload catch, provision, bunkering, repair and maintenance or crew change-over.

The location of fishing activity varies according to the fishery and target species. MPI provides maps showing the general spatial pattern of commercial inshore trawl, net and line fishing activity[7]. For example, inshore trawl fishing activity occurs around virtually all of the New Zealand coastline, apart from Fiordland[8]. By contrast, specific fisheries have a more restricted geographic range. Statistics for all commercial fisheries, and other fishing methods, are available grouped to statistical areas from the NABIS website (www.nabis.govt.nz).

The inshore fishing fleet is very diverse and general patterns of domestic movements of vessels are not easily determined as they do not always follow defined schedules or routes. Movements in New Zealand waters of all domestic fishing vessels >28 m length, all foreign-registered and foreign charter vessels, and all vessels <28 m total length fishing for orange roughy or scampi are monitored by the MPI Vessel Monitoring Service. Available registration figures do not differentiate between smaller fishing vessels requiring permanent berths and the multitude of trailer-borne small craft (Dodgshun et al. 2007). In 2007, the largest numbers of registered fishing vessels were domiciled in Auckland, Bluff, Nelson and Picton (Dodgshun et al. 2007). Secondary locations included the Chatham Islands, Kaipara, Lyttelton, Manukau, Napier and Tauranga, Whangarei and Wellington.

Hayden et al. (2009) investigated the domestic movements of large (>99 GT) vessels (including fishing vessels) in the years 2000-2005, and small fishing vessels (≤99 GT) in 2004-2006. Around 90% of port visits by large fishing vessels were to the ports of Timaru, Lyttelton, Nelson and Auckland where major seafood processors are located. Movements of small fishing vessels were determined from a survey of 307 licensed operators (Hayden et al. 2009), detailing movements between 581 pairs of locations (Hayden et al. 2009). Only 161 of

[7]http://www.fish.govt.nz/en-nz/Aquaculture/Maps+of+Commercial+Inshore+Fishing+Activity/default.htm
[8]http://www.fish.govt.nz/en-nz/Aquaculture/Maps+of+Commercial+Inshore+Fishing+Activity/Trawl+Fishing+Maps.htm

these made trips outside their domiciled location to other ports and marinas, of which about half made only one trip/year. The remainder made only trips to and from their home ports.

5.5 Modes of infection

Commercial fishing activities can potentially transport harmful marine organisms in a number of ways (Carlton 2001, Hewitt & Campbell 1999, Hewitt & Campbell 2010).

- Through uptake in **ballast water** used to control the stability of large vessels.
- As **biofouling** attached to wetted surfaces of the hull or 'niche' areas (e.g., dry-dock support strips, sea-chests, propeller, rudder, exposed surfaces of water piping, thruster tunnels, etc.).
- As **biofouling** attached to **mobile structures** used in commercial fishing (e.g., buoys, ropes, anchors, etc.).
- Through uptake in seawater used for other **ship-board operations** (e.g., bilges, cooling water, holding tanks, etc.).
- As **contaminants** picked up unintentionally during deployment and retrieval of fishing equipment (e.g., nets, chains, pots, etc.).
- Through **transfer of livestock and bait** (e.g., holding pens, bait wells, etc.).
- As contaminants picked up unintentionally in material removed from the seabed (e.g., **benthic trawls**).
- Through deliberate movement of **live catch of harmful organisms**.
- As contaminants associated with the movement of live catch and associated equipment.
- As waste discharged from processing facilities.

5.5.1 Ballast water

Most commercial fishing vessels operating in New Zealand do not regularly utilise seawater for ballast. Those that do are predominantly larger vessels (>40 m length) that operate in the deep-water fishery. These vessels carry relatively small volumes of ballast water compared to merchant bulk carriers and tankers. For example, in an analysis of the ballast capacity of US flagged vessels >300 GT in size, 99% of the fishing vessels in this category carried <1,500 m^3 of ballast water. This is less than ⅓ of the volume carried by dry bulk carriers, tankers and container vessels, which all typically had ballast capacities >5,000 m^3 (King et al. 2012).

Smaller fishing boats manage stability through loading of consumable liquids (e.g., fuel, freshwater, sewage), stores and catch (Fish Safe 2003, Maritime New Zealand 2011b). Seawater carried on-board is often chilled or heavily brined for storage of catch, thereby reducing the likelihood that harmful marine organisms could survive in it.

5.5.2 Bilges and other water containing-spaces and discharges

Fishing vessels invariably take seawater into the bilge, with discharge normally operating 'on-demand' to ensure vessel stability/safety. Bilge water may pose a risk for the spread of entrained organisms (Cawthron Institute 2013, Darbyson et al. 2009b), in particular for smaller organisms and pathogens. The extent of this risk has received comparatively little study.

5.5.3 Biofouling

Biofouling has been observed on international and domestic fishing vessels in New Zealand waters, with generally low-to-moderate levels of fouling recorded (Gust et al. 2005, Gust et al. 2008, Piola & Conwell 2010). The amount of biofouling on a vessel will vary depending on its operations (e.g., time at sea, in port and laid-up; operating speed, etc.) and maintenance programme (e.g., appropriate use of anti-fouling coatings, schedule of survey inspections and dry-docking, etc.). Biofouling can lead to the spread of harmful marine organisms either through passive (unintentional) discharge of reproductive or other viable organic material or through the intentional removal of biofouling through hull cleaning during which viable material enters the marine environment, survives and becomes established.

Large fishing vessels also possess sea-chests and other areas for seawater in-take. Sea-chests provide a relatively sheltered environment for free-living and sessile marine organisms and can pose a significant biosecurity risk (Coutts & Dodgshun 2007). Similar to merchant vessels, observations of fishing vessels under maintenance show a greater propensity for fouling around niche areas than on the general hull (Coutts & Dodgshun 2007).

A B C

Figure 5-1. Biofouling on the hulls of small, coastal commercial fishing vessels domiciled in the Port of Lyttelton, including the non-indigenous ascidian, *Styela clava* (A), the native ascidian *Boltenia pachydermatina* (B) and the non-indigenous caprellid amphipod, *Caprella mutica* (C). (Photos: C. Woods, NIWA).

Figure 5-2. Examples of hull biofouling on large fishing vessels undergoing out-of-water maintenance in the Port of Lyttelton (Photos: C. Woods, NIWA).

5.5.4 Contaminants – equipment and fishing gear

Commercial fishing in New Zealand utilises a range of fishing methods and equipment (Table 5-1). Trawling (bottom and mid-water) is probably the most important commercial fishing method used in New Zealand, particularly for deep-water species. Mobile pelagic capture equipment that is only temporarily deployed (e.g., trawls, trolling, etc.) may pose some risk of entrainment of propagules, planktonic organisms and other drifting material (e.g., drifting seaweed clumps and associated biota) that could be transported to other locations with the gear. Static fishing equipment deployed for longer periods before retrieval (e.g., lobster and cod pots and their associated lines and buoys) can also be colonised by a range of fouling and mobile organisms. Equipment used on the seafloor (e.g., scallop, oyster and clam dredges) can capture a range of other, non-target organisms. There is a risk that harmful marine organisms may be transported with this equipment to other fishing grounds or to port if it is moved without being thoroughly cleaned. The extent of this risk has not been investigated in detail within this sector in New Zealand.

Diving equipment (and other associated fishing gear) used in the commercial paua and kina fisheries may also pose a risk for transport of microscopic organisms or fragments of algae and other organisms capable of vegetative regrowth. The risks associated with this equipment are also discussed in Sections 6.1.3 and 7.4 of this report. Practices available to reduce risk of transfer by diving equipment are summarised in Sections 6.9 and 7.12 and in Table 4-3.

5.5.5 Processing of product

Processing of fisheries product can occur at sea or at land-based facilities, with varying degrees of discharge (and treatment) of processing waste. If facilities discharge untreated or inadequately treated waste-water into the sea there is a possibility for transfer of viable harmful organisms (Biodiverse Limited 2010). MPI Risk Management Plans (RMP) for processing and rendering of seafood product at sea- and land-based operations are primarily directed at food safety rather than the spread of non-indigenous marine organisms.

5.6 Available practices to reduce risk – ballast water

In general, the measures and considerations described in Section 3 for treatment of any ballast water on domestic merchant vessels will also apply to large vessels that carry ballast in the commercial fishing sector.

The Ballast Water Management Convention (Section 3.5.1) will not apply to New Zealand flagged fishing vessels that operate only within New Zealand waters. However, when the convention comes into force, New Zealand fishing vessels that carry ballast water and that operate within the coastal waters of other countries will be required to meet the standards specified in the convention. Vessels constructed before 2009 will be required to at least meet the ballast water exchange standards or the ballast water performance standards until 2016 (Section 3.5.1). After 2016 they will be required to meet the ballast water performance standard, which will typically mean retrofitting an IMO approved ballast water treatment system.

5.7 Assessment of options – ballast water

Effectiveness

A discussion of the effectiveness of ballast water exchange and ballast water treatment systems for reducing biosecurity risk is given in Section 3.6.

Few, if any, vessels in the inshore fishing fleet are likely to carry seawater as ballast. Exchange of ballast water in coastal waters will be less effective than open-ocean exchange (defined in the Ballast Water Convention as at least 50 nm from the nearest land and in water at least 200 depth) and can, in some cases, enhance the survival and abundance of potentially harmful species (McCollin et al. 2007).

Discharge of coastal ballast (i.e., that taken up in port) by deep-water fishing vessels in New Zealand is most likely to occur on fishing grounds beyond the Territorial Sea as catch is loaded and may, therefore, present a relatively low biosecurity risk. Similarly, any ballast taken on in the open ocean environments of the EEZ may contain relatively small concentrations of larvae from coastal species and, thereby, pose low risk to coastal environments.

Practical feasibility

As with merchant vessels, safety is of paramount importance in managing the stability of fishing vessels. For medium-sized (>40 m) vessels operating on the EEZ, ballast water exchange may not be a safe option in many circumstances.

Cost of compliance and expected rate of uptake

The costs of retrofitting and operating IMO-approved ballast water treatment systems were discussed in Section 3.6.4. In general, it is unlikely that many domestic vessels will be able to afford the types of ballast water treatment systems that are coming onto the global market (King et al. 2012). Cheaper treatment methods (e.g., dosing internal water spaces with chlorine or other approved chemicals, Section 3.6.2) may be more feasible, but need to be balanced against the safety considerations of carrying large quantities of chemicals on board the vessels and the environmental consequences of their discharge with treated water.

5.8 Available practices to reduce risk – bilge water

Maritime New Zealand requirements for discharge or retention of bilge water by registered commercial vessels operating in New Zealand waters were described in Section 3.8 of this report. In general, New Zealand fishing vessels >400 GT must have oil filtering equipment installed that is designed to ensure that discharged water has an oil content that does not exceed 15 ppm (Maritime New Zealand 2011e). Vessels <400 GT must meet the discharge standard for larger vessels or be able to retain all oily wastes on board for discharge to a reception facility on shore (Maritime New Zealand 2009). As discussed in Section 3.8, these systems may mitigate some biosecurity risk, by screening out large organisms or fragments from the bilge before it is discharged, but it is unclear to what extent they are likely to remove the planktonic stages of potentially harmful species.

Practices recommended for treatment of bilge for merchant vessel in Section 3.8 will generally also be applicable to commercial fishing vessels. These recommended practices are:

- discharge and emptying of water before departing from a location,
- retention and storage of water for discharge to shore-based treatment,
- regular flushing with freshwater or an approved treatment as a preventative measure to keep the spaces clean, or,
- treatment of water spaces with an approved treatment (Cawthron Institute 2013, Commonwealth of Australia 2009b, International Maritime Organization 2012, MAF Biosecurity New Zealand 2007a).

5.9 Assessment of options – bilge water

Evaluations of the effectiveness, practical feasibility, costs of compliance and expected rate of uptake for bilge treatment systems are presented in Section 3.8 of this report and in the accompanying Part B report (Sinner et al. 2013).

5.10 Available practices to reduce risk – biofouling on vessels

The Australian commercial fishing industry has, in consultation with Australian State and Commonwealth governments, developed national guidelines for management of biofouling on trailered and non-trailered fishing vessels (Commonwealth of Australia 2009a). These provide information to vessel owners and operators about practices for the maintenance and operations of fishing vessels that will reduce the risks of transporting potentially harmful species. For trailered vessels, these include:

- checking for, and removing entangled or attached biological matter from the boat and trailer,
- checking the outboard and hull fixtures for water that could harbour potentially harmful organisms,

- rinsing the boat inside and out with freshwater, draining and, if possible, allowing it to dry before moving to another location within 48 h,
- regularly removing slime from the hull to prevent build-up of secondary biofouling, and
- disposing of any biological material, including organisms known to be harmful to bins or landfill so that it cannot be returned to the water (Commonwealth of Australia 2009a).

For non-trailered vessels, the guidelines provide information on hull cleaning and the use of anti-fouling coatings appropriate to the vessel's operations and hull maintenance. Recommended practices include:

- removal of biofouling in shore-based facilities with all waste material disposed of on land,
- regular flooding of internal seawater spaces with freshwater to kill any marine organisms, particularly prior to moving between regions, and
- anti-fouling coatings should be applied by an approved operator in accordance with the manufacturer's specifications and should be renewed according to the minimum service life recommended by the coating manufacturer.

The guidelines also recommend regular inspection of painted and unpainted surfaces of the vessel to determine the need for biofouling to be removed or for re-painting to occur and that records should be kept of all anti-fouling activities and inspections (Commonwealth of Australia 2009a).

Like other registered commercial vessels, fishing vessels in New Zealand are required to comply with the Safe Ship Management (SSM) requirements of the Maritime Transport Act 1994 (Maritime Rule Part 21; Maritime New Zealand 2011c). Maritime Rule 46.17 requires vessels under an approved SSM system to undergo an out-of-water inspection of the hull and external fittings every two years (Maritime New Zealand 2011d). The period between these inspections may be extended for ships ≥24 m in length that have steel or aluminium alloy hulls. Granting an extension is at the discretion of the organisation managing the SSM and will need to ensure that at least two such inspections are carried out in any 5 year period with no more than 3 years between any two inspections (Maritime New Zealand 2011d). These regular inspections provide an opportunity for vessel operators to assess biofouling on the vessels and to implement in-water or out-of-water cleaning, where necessary.

5.11 Assessment of options – bilge water

Effectiveness, feasibility, cost of compliance and expected rate of uptake

Like other commercial vessels, fishing vessels should be encouraged to implement Biofouling Management Plans into their operations to detail the measures taken to minimise biofouling. Effective management of biofouling requires use of anti-fouling systems appropriate to the operational profile of the vessel, regular inspection of submerged surfaces and maintenance of anti-fouling protection. Sections 3.10 and 3.10.3 contain discussions on considerations for use of haul-out facilities and in-water cleaning of large commercial vessels in New Zealand to manage biofouling risks.

A B C

Figure 5-3. Examples of out of water vessel maintenance on commercial fishing vessels in (A) Lyttelton dry-dock, (B) Lyttelton and (C) Dunedin port slipways (Photos: C. Woods, NIWA).

5.12 Available practices to reduce risk – contaminants on equipment and fishing gear

Recommendations on approaches to mitigate biosecurity risk within the commercial fishing industry are discussed in Commonwealth of Australia (2009a). These include:

- ensuring that dive gear is inspected and washed so that biological material entangled in it is not transported to other sites,
- sourcing bait locally, wherever possible,
- returning by-catch that isn't required to be landed to the sea as near as possible to the point of capture,
- cleaning of gear on land and disposal of biological waste to landfill,
- streaming nets as close as possible to fishing grounds,
- if a potentially harmful marine organism is in the fishing ground or one is suspected to be, nets should not be streamed to clean them,
- drying nets regularly or prior to transfer to another boat to ensure living biological matter is not translocated.

Effectiveness

Routine inspection and washing of equipment with fresh- or saltwater followed by air-drying, or soaking in hot water and detergent will mitigate most biosecurity risk associated with deployment of fishing gear (Table 4-3; Commonwealth of Australia 2009c). Care should be taken to ensure that washings and biological material are disposed of appropriately, as some organisms or their offspring will survive the cleaning process. Where the equipment is cleaned at the site of origin, then returning the wastes to the sea may pose minimal biosecurity risk. Where possible, however, the recommended practice is to retain the waste for disposal to landfill on shore.

Soaking in freshwater, hot water or detergents is most suited to smaller items of deployed equipment that have not been heavily fouled (e.g., ropes, anchors, transducers, etc.). The effectiveness of the treatment will depend on duration over which the equipment was soaked and if any disinfectant or detergent is used to kill any associated organisms (Table 4 3).

Feasibility, cost and rate of uptake

In general, the measures recommended for cleaning immersible equipment are readily available and low cost to implement for most types of equipment. Uptake is unlikely to be limited by the cost of implementation, but will depend on the extent to which the sector and individual companies incorporate these measures into their standard operating procedures.

5.13 Available practices to reduce risk - processing of product

For land-based processing of product, resource consents are required for waste-water discharge to water or land. Trade waste consents are required for discharge to sewerage systems. Thus, controls on these activities can be put in place by regional authorities as to hygiene standard required to prevent release of potentially harmful organisms (macroscopic and microscopic).

5.14 Commercial fishing pathway – summary of recommendations

Risks of the domestic transfer of harmful marine organisms within the commercial fishing sector are principally associated with the movement of vessels (trailered and non-trailered), gear and livestock (catch and bait) between regions.

Biofouling risk can be mitigated through appropriate use and maintenance of anti-fouling coatings that are suited to the vessel's operational profile and by regular inspection and removal of biofouling in ship-yard facilities. Like other commercial vessels, domestic fishing vessels are required to undergo regular out-of-water inspections under SSM and consideration should be given to development and maintenance of an auditable BMP for fishing vessels and to an industry Code of Practice (CoP) that details Standard Operating Procedures for managing risks from bilge water, biofouling and contaminants on fishing equipment and for movement of livestock and bait. Practical options for decontaminating equipment include streaming of nets prior to relocation, water-blasting, washing and air drying. Simple measures are available to reduce risks from trailered vessels and immersible equipment, diving equipment, anchors, etc. These include inspection, cleaning and drying of the vessel, trailer and equipment after each journey or trip, removing attached biofouling or entangled organisms and rinsing and drying hull compartments.

Industry training in the CoPs and independent audit will encourage greater uptake of best-practice within the sector. There is a need to establish the risks associated with transport and discharge of bilge water and how existing oil-water separation systems may mitigate that risk. Practical options, such as discharge before moving to a new location, fitting of in-line filters, or storage of bilge for discharge to waste reception facilities on-shore, should be encouraged in the interim.

6 Marine aquaculture

The RMA defines aquaculture activities as:

- any activity described in section 12 of the Act done for the purpose of the breeding, hatching, cultivating, rearing, or on-growing of fish, aquatic life, or seaweed for harvest if the breeding, hatching, cultivating, rearing, or on-growing involves the occupation of a coastal marine area, and
- includes the taking of harvestable spat if the taking involves the occupation of a coastal marine area, but
- does not include an activity specified above if the fish, aquatic life, or seaweed:
  - are not in the exclusive and continuous possession or control of the person undertaking the activity, or
  - cannot be distinguished or kept separate from naturally occurring fish, aquatic life, or seaweed, and
- does not include an activity specified in paragraph in the first two bullet points above if the activity is carried out solely for the purpose of monitoring the environment.

Aquaculture is currently worth more than NZ$380 million per annum to the New Zealand economy. The industry has a goal of increasing annual sales to NZ$1 billion by 2025[9]. In 2012, the Government adopted the Aquaculture Strategy and Five-year Action Plan[10], an action plan that establishes a whole-of-government pathway to enable the aquaculture sector to grow in accordance with the industry's strategy.

Around 23,000 ha of water space are currently allocated for marine-based aquaculture in New Zealand. Of this space, approximately 56% is near shore, 38% is considered open-ocean, and 6% is undeveloped space in interim aquaculture marine areas[11].The principal regions for marine aquaculture in New Zealand are: Northland, Auckland, the Coromandel, Tasman and Golden Bays, the Marlborough Sounds, Canterbury and Stewart Island[12]. Freshwater and land-based aquaculture facilities are scattered around New Zealand (Morrisey et al. 2010).

Aquaculture production is currently dominated by Greenshell™ mussels (38,143 t exported in 2011), Chinook salmon (5,166 t) and Pacific oysters (1,667 t)[13]. Blue mussels, Bluff oysters and paua (abalone), koura, and freshwater prawns are also farmed to a smaller degree. Species still in the research, pre-commercial or nascent commercial stages include eels, European perch, sea cucumbers, kina, rock lobsters, kingfish and groper/hapuku. Following a review, the government has also decided to allow a broader range of commercial uses of the non-indigenous seaweed *Undaria pinnatifida*, with *Undaria* now allowed to be farmed in selected, heavily infested areas (subject to MPI approval) and to be harvested from artificial surfaces (Office of the Minister for Biosecurity 2010).

There have also been several notable incursions of non-indigenous biofouling organisms into New Zealand that have affected production and costs to the aquaculture industry or which have the potential to do so. These include the ascidians *Styela clava* (Gust et al. 2006),

---

[9] http://aquaculture.org.nz/industry/

[10] http://www.fish.govt.nz/NR/rdonlyres/20A0ED89-A20B-4975-9E63-6B302187840D/0/AQUAStrat5yrplan2012.pdf

[11] http://www.fish.govt.nz/en-nz/Commercial/Aquaculture/default.htm

[12] http://aquaculture.org.nz/wp-content/uploads/2012/05/NZ-Aquaculture-Facts-2012.pdf

[13] http://www.mpi.govt.nz/news-resources/news/areas-designated-for-undaria-farming

Didemnum vexillum sp. (Denny 2008) and *Eudistoma elongatum* (Morrisey et al. 2009), and the tube worm *Sabella spallanzanii* (Inglis et al. 2008).

6.1 Modes of infection

Marine aquaculture can contribute to the spread of harmful marine organisms in the following ways.

- By **providing habitat** for harmful biofouling organisms.
- As **biofouling attached** to the wetted surfaces of the hull or niche areas (e.g., dry-dock support strips, sea-chests, propeller, rudder, exposed surfaces of water piping, thruster tunnels, etc.) of **vessels** used in the industry.
- As **biofouling attached to mobile structures** used in marine farming (e.g., spat catching gear, buoys, ropes, anchors, mooring blocks, finfish cages etc.) (Biodiverse Limited 2010, Dodgshun et al. 2007, Morrisey et al. 2010).
- Through **uptake in seawater** used for ship-board operations (e.g., bilges, cooling water, holding tanks, etc.).
- As contaminants picked up unintentionally during deployment and retrieval of marine equipment (e.g., anchors, chains, mooring ropes, etc.).
- Through deliberate movement of spat/seed-stock or adult product.
- As contaminants associated with the movement of spat/seed-stock and associated equipment.
- As waste discharged from processing facilities (Fitridge et al. 2012, Forrest et al. 2009, ICES 2005b, Locke et al. 2007, Lutz-Collins et al. 2009, McKindsey et al. 2007, Minchin 2007).

Biosecurity risks associated with aquaculture activities have been detailed in a number of recent reports and reviews of the environmental effects of aquaculture in New Zealand (e.g., Forrest et al. 2011, Forrest et al. 2007a, Keeley et al. 2009).

Practices that involve the collection and re-location of marine organisms for use as food for cultured organisms may also be a pathway for spread of harmful marine organisms. Examples could be the collection of seaweeds for feeding to paua at land-based facilities or in sea-cages (barrels) and live mussel transfers for use in feeding crayfish in holding units or even as bait for crayfish.

6.1.1 Service Vessels

The aquaculture industry utilises a variety of vessel types for its operations. These range from mussel harvesters/seeding vessels and finfish transporters to small launches and dinghies. Motorised and towed ('dumb') barges of various sizes may also be used to transport stock, equipment and various farm supplies and as working/plant platforms. Vessel movements associated with aquaculture may occur in relation to farm construction (e.g., screw-anchor deployment for conventional mussel long-lines), farm servicing, and harvesting. Because of their small size, vessels operating in the aquaculture industry do not carry ballast water.

Bilges and other water containing-spaces and discharges

Like other vessel types, seawater accumulates in the bilge of aquaculture vessels as a result of deck runoff (e.g., live mussels held in sacks on vessel deck may leak fluids en route during transit) and discharge or overflow from holding tanks. For example, the transfer of salmon smolt to marine farms may utilise flow-through pumping of seawater to maintain fish. Discharge of water from these sources will often occur while the vessel is in transit. For many vessels, discharge of bilge occurs automatically to ensure vessel stability/safety.

Biofouling

Patterns of biofouling on aquaculture vessels in New Zealand have not been investigated to the extent that they have for other vessel types (e.g., merchant, fishing and recreational). Nevertheless, as with other vessel types, the amount of biofouling present on the submerged surfaces of aquaculture vessels will depend on the time they spend in the water, their activity, and the schedule of maintenance and anti-fouling (See Section 3.4.3).

Movements of aquaculture vessels between ports or regions of New Zealand are not typically monitored. Most aquaculture service vessels tend to operate within a single farming region. According to Forrest and Blakemore (2002), movements of mussel farm equipment and service vessels occur infrequently between different regions and, where they do occur, follow the same pathways as for spat and seed mussels (see also Section 6.1.3). As an example, Gust et al. (2008) described two mussel harvesting vessels that frequented the Port of Lyttelton, but which also service farms in the Marlborough Sounds. Each vessel operated in the Banks Peninsula region for between 1 to 4 months each year, making regular trips between farms around the peninsula and the Port of Lyttelton. Outside of this time they operated in the Marlborough Sounds, working on farms in Port Underwood, Pelorus Sound and Queen Charlotte Sound.

6.1.2 Mobile infrastructure

Biofouling

Most infrastructure involved in sea-based aquaculture could be considered mobile (cf. land-based aquaculture infrastructure), as structures are not fixed permanently to the seabed and can be removed if necessary.

Mobile infrastructure includes an assortment of equipment that may be totally or partially-submerged in seawater (e.g., cages, nets, floats, fixed barges, anchors and ropes etc.). All of these surfaces can develop biofouling (Fitridge et al. 2012, Greene & Grizzle 2007, Sliskovic et al. 2011). Structures that remain in seawater for long periods can develop substantial biomass of biofouling and present a biosecurity risk if they are moved to new locations without being cleaned (Forrest et al. 2011). For example, multi-filament netting material can be heavily colonised by biofouling, with growths of up to 8.5 $kg.m^{-2}$ recorded in some areas after just 5 months deployment (Braithwaite et al. 2007, Hodson et al. 1997). Biofouling growing on cages and nets may also present biosecurity risks to the farmed stock, as hosts of pathogenic microorganisms and parasites (e.g., viral pathogens, bacteria, blood flukes etc.) (Fitridge et al. 2012, Forrest et al. 2011). For example, Amoebic gill disease (AGD) in salmon is caused by a marine amoeba, *Neoparameoba pemaquidensis*, that has been associated with biofouling organisms such as the solitary ascidian *Ciona intestinalis* (Tan et al. 2002).

Translocation of aquaculture infrastructure in New Zealand typically involves short distance movements within a farming region (Dodgshun et al. 2007, Forrest et al. 2007a, T. Culley, Sanford Ltd. pers. comm.). Movement of finfish sea-cages may occur within farming regions for site-fallowing purposes. For example, New Zealand King Salmon move finfish cages between Waihinau Bay and Forsyth Bay in the Marlborough Sounds for site-fallowing, with in-water cleaning of the most-heavily fouled outer predator nets occurring before the cages are moved. Nevertheless, because not all fragments of the organisms are effectively removed during cleaning, there is still potential for some organisms to be spread within the region (Forrest et al. 2011). Where sea-cages have been moved between farming regions, they have usually been refurbished before transfer (i.e., cleaned and repainted, Dodgshun et al. 2007).

Movements of mussel gear (floats, anchors, backbone ropes, mooring blocks etc.) are also mostly restricted to within local farming regions (Forrest & Blakemore 2002).

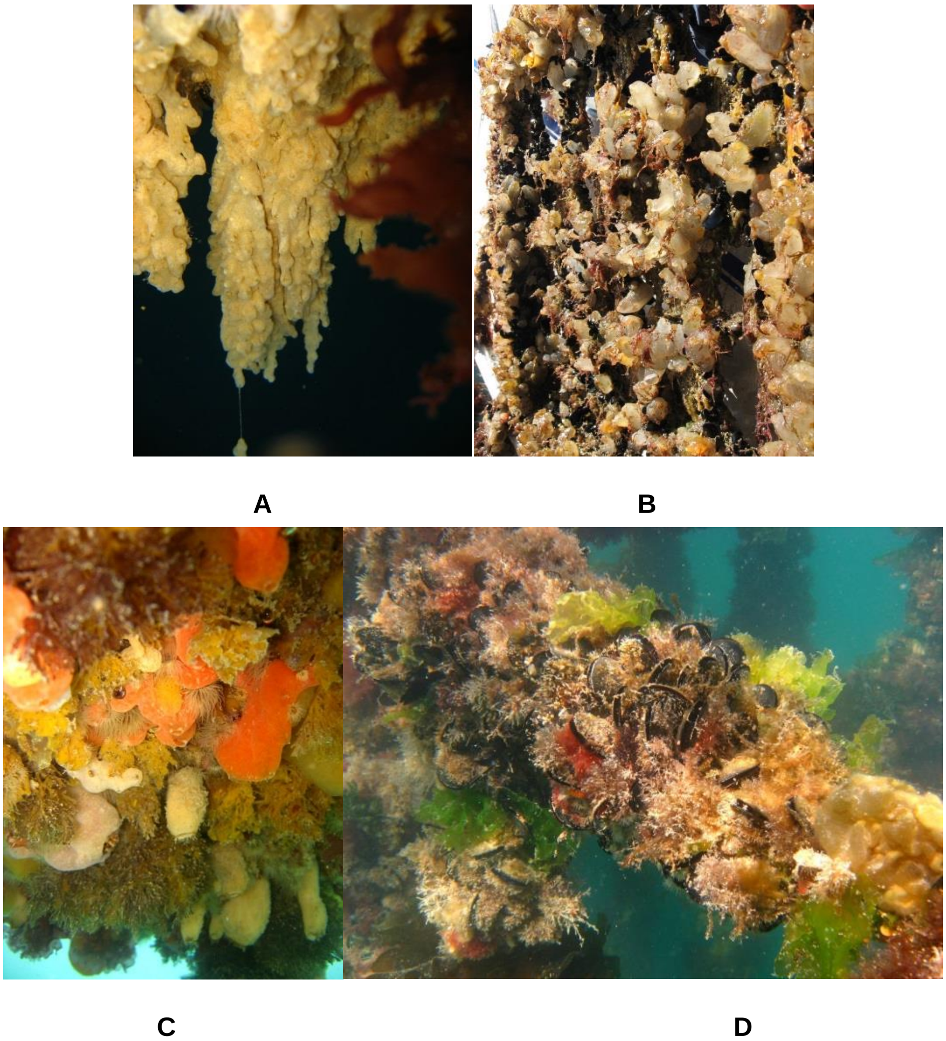

Figure 6-1. A) the colonial ascidian *Didemnum* growing from a salmon farm cage pontoon, B) the non-indigenous solitary ascidian, *Ciona intestinalis* and caprellid amphipod, *Caprella mutica*, on salmon cage predator netting, C) general biofouling on the underside of a mussel float and D) backbone line in the Marlborough Sounds (Photos: C. Woods, NIWA).

Overall, there is limited information regarding specific biosecurity risks involving biofouling and potentially harmful marine organisms associated with mobile aquaculture structures in New Zealand. However, the clear linkage between aquaculture activities and introduction and spread of non-indigenous marine organisms (e.g., Fitridge et al. 2012, McKindsey et al. 2007, Minchin 2007), and the existence of international codes and guidelines concerning movements of aquaculture infrastructure (e.g., Aquaculture of Western Australia (ACWA) 2013, ICES 2005c), indicate that this pathway does need to be managed.

6.1.3 Livestock and associated equipment

Biofouling

For this report, we have defined “livestock” as marine organisms being held for use or consumption including juveniles for growing in aquaculture facilities. It also includes harvested fish (finfish and shellfish) or other marine species that may no longer be alive. “Associated equipment” refers to the materials associated with livestock that may be moved with them when they are moved (e.g., mussel long-lines, oyster sticks/trays etc.).

Translocations of aquaculture stock and associated production equipment are known to be an important vector for the spread of “hitch-hiking” organisms (i.e., species moved unintentionally with the stock; Forrest et al. 2009, Locke et al. 2007, McKindsey et al. 2007, Minchin 2007, Torchin et al. 2002). In New Zealand, transfers of mussel seed-stock have been implicated in the spread of the Asian kelp, *Undaria pinnatifida*, from the Marlborough Sounds to the Firth of Thames (Forrest & Blakemore 2002) and in the spread of the ascidian, *Didemnum vexillum*, in the Marlborough Sounds (Forrest et al. 2011).

Shellfish provide a suitable surface for settlement and growth of a variety of biofouling organisms (Fitridge et al. 2012). For example, Woods et al. (2012) recorded 71 distinct taxa of biofouling organisms from Greenshell™ mussel ropes in Pelorus Sound, comprising~15% of the total biomass at final harvest. This biofouling was dominated by suspension-feeding organisms (~88% of biomass) such as other bivalves, ascidians and bryozoans.

Seed-stocks for shellfish (“spat”) are still sourced predominantly from the wild in New Zealand, with a limited number of locations suited to spat collection. Collected spat may be transported to marine farms throughout New Zealand along with other organisms that have settled on the substrata used to catch spat (Dodgshun et al. 2007). Inter-farm movements of mussel stock are not common beyond the spat/seed stage. However, regular inter-farm and inter-region movements of Pacific oysters may occur, mainly between the east and west coasts of northern New Zealand from the Kaipara Harbour.

Currently, around 60% of the spat used in the Greenshell™ mussel industry is collected from beach-cast material on 90 Mile Beach, Northland. The remaining 40% is sourced within Golden Bay and Tasman Bay. Collection and distribution of spat from these areas to production sites in other parts of New Zealand is a risk for the spread of toxic algal cysts, bacteria and other, secondary species unless the spat is treated before transport (Aquaculture New Zealand 2007).

Until recently, around 70% of the year-round supply of oyster spat to farms in the northeast harbours and Coromandel area came from settlement sites in the Kaipara Harbour, with occasional reverse transfer occurring from other areas in response to reduced water quality or settlement (Coutts & Dodgshun 2007). These movements and the return of settlement sticks to harbours on the west coast of the North Island from other growing areas, represent a risk for transfer of potentially harmful marine organisms if they are not cleaned before being returned (Fisheries Research and Development Corporation 2011).

A

B **C**

Figure 6-2: Non-indigenous marine organisms on Greenshell^{TM} mussel lines in the Marlborough Sounds. A) the macroalga, *Undaria pinnatifida*. B) the caprellid amphipod, *Caprella mutica*. C) the ascidian, *Ciona intestinalis* (Photos: C. Woods, NIWA)..

Recent advances have been made in New Zealand regarding commercial-scale production of hatchery Greenshell™ and Pacific oyster spat, with a focus on the provision of a reliable year-round supply of spat selectively-bred for certain growth and product traits. A prominent example is SPATNZ (Shellfish Production and Technology New Zealand Ltd), which was formed in 2010 to commercialise hatchery spat production and selective breeding of Greenshell™ mussels. SPATNZ plans to build a pilot-scale mussel hatchery, with the first spat scheduled for production in 2015. The intention is to establish methods and equipment capable of producing spat for around 10,000 t/yr of crop by 2016, and then 30,000 t/yr by 2019 (Roberts 2013). Such commercial-scale hatchery production of spat for transfer to grow-out farms around New Zealand offers the potential to significantly reduce the risk of transfer of biofouling organisms, but there is still some potential for spread of organisms that may be present in the hatchery seawater system (Fisheries Research and Development Corporation 2011).

Paua seed are produced in land-based hatcheries and typically have relatively low levels of biofouling due to filtration of intake waters which removes most propagules of biofouling organisms. Movement of wild-caught algae as food for cultured paua carries the risk of transporting potentially harmful species into sea-ranch growing areas or into shore-based facilities.

Salmon grown in sea-cages are sourced from various domestic land-based freshwater hatcheries and, therefore, pose limited risk for transfer of harmful marine organisms due to their passage from a freshwater to marine environment (Dodgshun et al. 2007, Morrisey et al. 2010).

Forrest et al. (2011) summarised biosecurity risks associated with movements of seawater in which aquaculture organisms may be transported. These include transport of:

- planktonic dispersal stages (propagules) of potentially harmful marine organisms,
- fragments of colonial organisms, and
- harmful algal bloom (HAB)-forming microalgal species and other holoplanktonic organisms (including cyst stages).

Processing of product

Processing of harvested product usually occurs at land-based facilities, with varying degrees of water and discharge of treated effluent. If processing facilities discharge inadequately treated waste-water into the sea the possibility exists for transfer of viable marine organisms (Biodiverse Limited 2010). For example, in Scotland, processing plants were suggested as a possible source of pathogen for spread of salmon anaemia (ISA) to vessels (well-boats) that transport harvested stock to the plants (Murray et al. 2002). As noted earlier, in-transit vessel discharge of seawater/fluids (e.g., holding tank water exchange for salmon, fluids from harvested mussels and oysters) during transfer of stock to land-based facilities may also involve some risk.

Containment/contaminants – equipment and feeds

Entrainment of organisms in sediments and seawater and fouling or entanglement of species on equipment such as ropes, anchors, chains and associated vessel/infrastructure recesses (e.g., anchor wells) are also potential risks for movement of harmful marine organisms (Acosta & Forrest 2009, Dodgshun et al. 2007, Forrest et al. 2011).

The biosecurity risks involved with transporting organisms on diving equipment used on aquaculture facilities have not been evaluated formally, but there are anecdotal observations that suggest movement of small, mobile organisms (e.g., crabs, amphipods and isopods) and fragments or propagules of larger organisms (e.g., seaweed spores) may be possible (Figure 6-3). Within the aquaculture industry, salmon farming is the largest user of divers for farm maintenance, cleaning/changing of cage netting and retrieval of dead fish. Divers on these farms will typically be employees of the company and will undertake a range of other general duties on the farms in addition to diving. Diving work is undertaken as part of routine maintenance and is usually restricted to farms that the staff members are employed on farms, with their dive gear stored on-site. However, commercial dive companies contracted by the industry will travel between different farm sites for services such as predator net cleaning, net installation and maintenance.

Protective/insulative clothing used by oyster farmers (e.g., wetsuits worn when harvesting from intertidal racks) may also represent a risk if not treated or dried sufficiently before movement to other farming areas.

A B

Figure 6-3. A) Salmon farm diver preparing to enter the water to check for fish mortalities and cage integrity, and B) the non-indigenous caprellid amphipod, *Caprella mutica*, clinging to a diver's buoyancy compensator (Photos: C. Woods, NIWA).

Land-based farms

Most land-based hatcheries for marine species (e.g., paua, oyster and mussel spat, kingfish) have seawater intakes and discharges (commercial full-recirculation operations are uncommon). Intake and discharge of water are consented by regional authorities, with varying degrees of water treatment at intake and discharge.

Vectors for transport of harmful marine organisms into and out of land-based marine aquaculture may involve the collection and translocation of initial broodstock, discharge of waters that contain harmful organisms brought into the facility from other areas, transfer of aquatic life from one fish farm to another farm, transfer of stock to marine grow-out farms (see Section 6.1.2) or disposal/releasing of unwanted stock or biotic material (e.g., mollusc shells) into the wild. For example, escape of the non-indigenous shell deforming polychaete, *Terebrasabella heterouncinata*, into wild populations appears to have occurred through discharge of infested material from onshore facilities (Culver & Kuris 2000).

Hatcheries may also contain 'quarantined' non-indigenous organisms such as phytoplankton varieties to feed early developing stages of molluscan species or to enrich live food cultures such as *Artemia* sp. Overall, the level of risk posed by such facilities for non-indigenous marine organisms in New Zealand is largely unknown, but is suspected to be low compared to other vectors and pathways (Dodgshun et al. 2007).

Deliberate or accidental release

Deliberate and unintentional release of non-indigenous marine organisms may also occur as a result of aquaculture or fisheries activities (Grosholz et al. 2012, ICES 2005a, 2005b). Deliberate release/transfer of marine organisms in coastal areas may occur in reseeding or enhancement programmes. Such programmes are used as fisheries resource management tools where natural stocks have become depleted because of over-fishing, disease or habitat disturbance, or where natural recruitment is low.

Enhancement has been trialled in a number of fisheries in New Zealand, including: chinook salmon, rock oysters, bluff oysters, cockles, pipi, toheroa, tuatua, paua, scallops, mussels, snapper, and kingfish[14]. Recent examples include the reseeding trials of juvenile paua reared in land-based hatcheries that were planted out onto the coast in the Pau3, Pau4, Pau5A,

[14]http://www.fish.govt.nz/en-nz/info/aboutus/Organisation/Fisheries+Science/Enhancement+and+Marine+Farming.htm?&MSHiC=65001&L=10&W=enhancement%20&Pre=%3Cspan%20class%3d'SearchHighlight'%3E&Post=%3C/span%3E

Pau5B, Pau5D and Pau7 fishing areas[15] and the collaborations between local hapu from Waimarama, Pourerere and Porangahau, Ngati Kahungunu Iwi Incorporated and the Paua 2 Industry Association (PAUAMAC 2)[16]. An example of wild enhancement is the scallop enhancement programme in Tasman Bay, where wild 'primary spat' (attached to spat-catching substratum on suspended lines) and 'secondary spat' (detached spat/juveniles dredged from underneath spat lines) are harvested from spat-catching sites and then redistributed to grounds in Golden Bay and Tasman Bay (Mincher 2008). Translocation of older stock may also occur. For example, the movement of abalone stocks to areas with better growing conditions has been used as a fisheries management tool internationally, and is being looked at for use by the New Zealand industry[17].

Customary aquaculture practices outside of the commercial sector may involve the movement of marine biota to transitional areas, to areas nearer to people for later harvest, or to another area more conducive to growth or 'fattening'/conditioning before harvest. An example of this is the transfer of fish to holding pots either in a transitional situation or storage practice (Pataka concept), such as the collection of kina in northern New Zealand and holding these kina nets in accessible subtidal areas whilst feeding them on harvested seaweeds to condition ('fatten') them prior to harvest.

Deliberate release may also occur with the return of unwanted stock to the wild, such as the release of unwanted broodstock from hatcheries, return of under-sized/suboptimal-sized shellfish following harvesting/processing, or disposal of waste from harvested organisms. Such releases may not always be back into the area of initial collection.

The Auckland Regional Council are currently investigating restoration of benthic mussel reefs in the Hauraki Gulf that would involve seeding mussels onto shell reefs from either a dedicated farm or using stock from exiting commercial farms[18].

Deliberate release of marine organisms may occur without any regulatory approval. For example, the introduction into California of the non-indigenous clam, *Corbicula fluminea,* and Chinese mitten crab, *Eriocheir sinensis*, are thought to have occurred as a result of deliberate release by individuals hoping to start harvestable populations (Grosholz et al. 2012).

Each of the vectors described above brings with it the risk of unintentional release of hitchhiking organisms. In the USA and Europe, for example, movement of oysters has been implicated in the transfer of a number of harmful species, such as slipper limpets (*Crepidula fornicata*), Atlantic oyster drills (*Urosalpinx cinerea*), and seaweeds such as *Undaria pinnatifida* (Dodgshun et al. 2007). Other forms of accidental releases can include escape of stock from containment in situ or during transit, such as fish escapes from sea-cages due to storm or predator damage, vandalism or operator error, or unintentional organism release from hatcheries.

6.2 Available practices to reduce biosecurity risk – general measures

6.2.1 International Measures

Internationally, measures introduced to reduce biosecurity risk within the aquaculture sector have typically involved the development of industry codes of practice (CoP) to complement official regulation of activities. Examples include the Federation of European Aquaculture

[15] http://www.paua.org.nz/reseeding.htm
[16] http://news.tangatawhenua.com/archives/16465
[17] http://www.paua.org.nz/translocation.htm
[18] http://www.aucklandcouncil.govt.nz/SiteCollectionDocuments/aboutcouncil/committees/haurakigulfforum/meetings/haurakigulffmag20121210.pdf

Producers Code of Conduct[19], the Code of Good Practice for Scottish Finfish Aquaculture[20], the Fish Health Code of Practice for Salmonid Aquaculture in Ireland[21], and the British Columbia Salmon Farmers Association Code of Practice[22]. Uptake of the CoPs by farmers is usually voluntary, but there is often provision for independent audit of the operations of those who sign up to the CoP to ensure that they comply with the principles contained within it.

In many of the examples cited above, the CoPs have intended primarily to manage risks to the health of livestock from pathogens and diseases, but many of the operational measures they proscribe also have utility for reducing risks associated with spread of harmful marine organisms. For example, the Scottish Finfish Code of Good Practice includes recommended procedures for:

- harvesting and transfer of livestock,
- tracking livestock movement (including to market),
- cleaning and disinfecting vessels, cages, moorings and other farming equipment,
- treatment of diving equipment,
- preventing build-up of biofouling on vessels, sea-cages and other equipment,
- preventing and managing escape of livestock, and
- managing waste from processing.

Each fish farming company that signs up to the CoP is required to develop a Veterinary Health Plan (VHP) and Biosecurity Plan (BP) for their operations in collaboration with a veterinary surgeon.

The International Council for the Exploration of the Sea (ICES), a marine science network comprising mostly northern European countries and the U.S.A., has developed a CoP on the *Introduction and Transfer of Marine Organisms* between member countries. The CoP provides recommendations for dealing with intentional movements of species that are new to a country and also recommends procedures for movement of species that are already part of existing commercial practice. The latter include recommendations for the following.

- Periodic inspection (including microscopic examination) of material prior to exportation to confirm freedom from introducible (*sic.*) pests and disease agents. If inspection reveals any undesirable development, importation must be immediately discontinued.
- Quarantining, inspection, and control, whenever possible and where appropriate.
- Considering and/or monitoring the genetic impact that introductions or transfers have on indigenous species, in order to reduce or prevent detrimental changes to genetic diversity.

6.2.2 New Zealand Measures

The aquaculture industry in New Zealand has also developed voluntary CoPs to mitigate the risks of spreading harmful marine organisms within its operations. CoPs have been

---

[19] http://www.aquamedia.info/consensus/
[20] http://www.thecodeofgoodpractice.co.uk/
[21] http://www.ifa.ie/LinkClick.aspx?fileticket=JnLUGHOaf7k%3D&tabid=611
[22] http://www.salmonfarmers.org/

developed for the mussel (Aquaculture New Zealand 2007), oyster (Aquaculture New Zealand 2007) and finfish industries (New Zealand Salmon Farmers Association 2007). These cover activities involved in farm development, operations, and emergency response and include measures to mitigate risks associated with movement of stock and equipment and procedures for managing stock health.

Routine preventative procedures

Both the mussel and oyster industries have cleaning processes for spat and livestock that assist in reducing associated biofouling. In the case of the mussel industry, a voluntary code of practice for seed-stock requires mussels to be subjected to a de-clumping and washing process before transfer, to restrict the transport of biofouling species with inter-regional movements across three geographic regions of New Zealand (Forrest & Blakemore 2002). This procedure greatly reduces macrofouling, but is less effective against resistant microscopic life-stages of some organisms, such as spores and gametophytes of the Asian kelp, *Undaria pinnatifida* (Forrest & Blakemore 2006). The oyster industry has a similar process referred to as ‘rumbling’ (Taylor et al. 2005).

Since 1993, the New Zealand Marine Biotoxin Monitoring Programme has implemented weekly collection of water samples from aquaculture and shellfish gathering sites around New Zealand, with microscopical analysis for target harmful algal bloom species (HABs). The target HABs tend to be those associated with biotoxins that contaminate cultured or wild shellfish and lead to illness in humans. The aim of the Marine Biotoxin Monitoring Programme is to minimise the risk that people will eat shellfish (recreational or commercial) that may be unsafe, with the weekly monitoring being a first step. Monitoring of phytoplankton is conducted at Ninety Mile Beach (Kaitaia spat collection area) with the aim detecting potential outbreaks of HABs. The industry has a stepped plan in response to detection of HABs and their cysts. Spat treatment is typically not conducted until deemed necessary as this adds cost to the industry. However, spat cleaning plants and spat holding facilities have been developed that can be used when ‘trigger’ levels are reached.

The New Zealand Mussel Industry Seed Code of Practice seeks to mitigate the risk of mussel seed transfers inadvertently transporting harmful marine organisms into areas they do not currently inhabit. Under the code, mussels transferred between the main farming regions should be de-clumped, washed and transported as ‘single seed’ visually free of several target species (i.e., blue mussels, and the non-indigenous species, *Ciona intestinalis*, *Styela clava* and *Undaria pinnatifida*) (Dodgshun et al. 2007, Forrest et al. 2009). Nevertheless, fragments of biofouling or microscopic life-stages may survive the de-clumping and washing process (Forrest & Blakemore 2006, Forrest et al. 2009). Prior to transferring mussel seed between three geographical zones, operators must ensure the seed meets specific criteria outlined in the CoP, and also complete an Interzone Mussel Seed Transfer Declaration for every interzone transfer.

The New Zealand Oyster Industry Code of Practice 2007 (Aquaculture New Zealand 2007) gives guidance to farmers to remove biofouling from posts and rails as the crop is harvested or before the farm is re-stocked, and it is noted that farmers should minimise farm discharge (including biofouling) during operations. Farmers are required to dispose of farm waste to an approved site on land. Washing-down of crops (with seawater) may be a standard part of farming procedures to control crop siltation and mudworm infestation. Oyster farmers are also required to adhere to Aquaculture New Zealand’s Biosecurity Code of Practice and its *Styela clava* Code of Practice (Aquaculture New Zealand 2007), the latter of which entails searching for *S. clava* during operations, removal and disposal of *S. clava*, and treatment of affected structures, among other steps.

The Finfish Aquaculture Environmental Code of Practice (2007) states that movements between farms (and other farm practices) shall adhere to any regulatory or voluntary Industry or Company Code of Practice for the management of disease vectors (New Zealand Salmon Farmers Association 2007). In addition, each farm/hatchery must undergo once-yearly assessments for the disease status of fish. Fish companies must also obtain MPI approval for transfer between farms prior to transport.

Passive surveillance has been promoted to some extent within the industry. The Aquaculture New Zealand Biosecurity Code of Practice requires farmers to inform MPI of any notifiable organism or organisms not normally seen or detected in New Zealand (Aquaculture New Zealand 2007). Cawthron has produced a biofouling identification guide for the Marlborough Sounds mussel industry to aid this practice, and in the Marlborough Sounds region marine farmers tend to be proactive in reporting suspicious organisms.

Reactive preventative procedures

During the southern New Zealand eradication programme for the kelp, *Undaria pinnatifida* (1997-2004), the mussel industry introduced a voluntary ban on movements of mussel seed-stock from the Marlborough Sounds to Big Glory Bay in Stewart Island, as this was recognised as a high risk pathway by which the microscopic life-stage of *Undaria* could be transferred (Hunt et al. 2009). Farmers also agreed to use new equipment or sterilise all ropes to minimise the risk of transferring *Undaria* into or around Big Glory Bay. Simultaneously, the mussel industry in several other regions participated in management programmes for *Undaria*, again via voluntary codes of practice.

A HAB species (*Gymnodinium catenatum*) bloomed off New Zealand's northwest coastline in 2000, with high densities of *Gymnodinium* cysts detected in cultured shellfish (mussel and oyster) spat (Mackenzie & Beauchamp 2001). This led to a voluntary ban on spat movements to all aquaculture regions in New Zealand. Treatments for both oysters and mussels were subsequently developed to minimise cyst densities within infected spat so that inter-regional transfers could continue (Taylor 2000; Forrest & Blakemore 2002).

In response to a population explosion of the sea squirt*, Ciona intestinalis,* in the Marlborough Sounds, the mussel industry, with government co-funding, developed a control method based on water-blasting. The widespread application of this method was, however, considered unaffordable by the industry.

The mussel industry in Marlborough led a regional response to the sea squirt *Didemnum vexillum* in 2006–2008, due to concerns regarding its effects on mussel farming. The programme consisted of both controls on potential vectors for its spread and population management. It was discontinued once the species became established to the extent that control was no longer considered feasible.

6.3 Management of risk pathways and vectors

In general, the practical measures and considerations described in Sections 3.8 and 3.10.1 for management of biosecurity risks in bilge water and biofouling on merchant vessels and in Sections 5.6.2 and 5.6.3 for commercial fishing vessels will also apply to vessels used in the aquaculture sector. Particular considerations for the aquaculture industry are described below.

6.4 Available practices to reduce risk - vessel biofouling

Vessels used in the aquaculture industry will be required to comply with the safe ship management (SSM) requirements provided under Maritime Rule Part 21 Section 2 (Maritime New Zealand 2011c) and will, therefore, typically be required to undergo out-of-water inspections of the hull and external fittings below the waterline at intervals not exceeding 2 years (see Section 3.4.3). Although the inspections for SSM are concerned with the structural integrity and safety of the vessel, they will typically require biofouling to be removed for the inspection to take place. As with other vessel types, these out-of-water inspections provide an opportunity to clean and anti-foul the vessels with appropriate antifouling coatings.

The Greenshell™ Mussel Industry Environmental Code of Practice 2007 (Aquaculture New Zealand 2007) recommends that anti-fouling of aquaculture vessels should be carried out regularly (to discourage fouling organisms and thereby minimise the risk of transfer and spread of harmful marine organisms) in an approved manner and at an approved facility.

6.5 Available practices to reduce risk - bilge water

As bilge water systems for medium sized vessels normally operate automatically 'on-demand' to ensure vessel stability/safety, there are inherent difficulties in regulating bilge water discharge. Best practice guidelines may be more appropriate to address this potential vector risk (e.g., 'empty before you go' with vessels discharging bilge water before moving to a different site/region). For example, New Zealand King Salmon has an internal policy of discharging bilge water before movement between sites (Mark Gillard, NZKS, pers. comm.).

Discharge of bilge water to land-based facilities for treatment may be an option at some ports, but would be difficult to implement at smaller, regional locations and for movements between aquaculture farms. Where they are not already in place, consideration should also be given to installing in-line filters on the bilge discharge line as an option for reducing biosecurity risk (see Section 3.7 of this report).

For other vessel water spaces and surfaces open to possible contamination, treatment and disinfection may be an option. For example, when well-boats transfer between areas, they may be inspected and disinfected, which should minimise the risk of cargo residue transferring harmful organisms, although removal of all fish and residue from pumps and pipework may be difficult.

The Scottish Finfish Aquaculture Code of Good Practice details a 3-stage cleaning and disinfection protocol for well-boats and specifies the conditions under which each stage is needed[23]. Stage 1 describes daily hygiene procedures that involve cleaning solids from all surfaces and pressure cleaning (with detergent) areas that have been in contact with fish. Stage 2 cleaning is required when a vessel plans to move to another production area. This involves steam cleaning and disinfecting all surfaces, including the hull, down to the water line. Stage 3 cleaning is for vessels arriving in UK waters from overseas or for vessels leaving sites known or suspected to be infected by a notifiable organism. In this case, the vessel is to be slipped, cleaned and disinfected, including below the water line.

Well-boats must travel closed (i.e., with no water exchange) when within 5 km of any finfish farm site and must not discharge stored water within 5 km or one tidal excursion (whichever is greater) of a farm site. This means that ballasting and pump cleaning need to be part of a vessel's passage plan, and are sequential operations. Similar management plans could be considered for aquaculture vessels under the New Zealand CoP's.

6.6 Available practices to reduce risk – biofouling on mobile structures

Generic measures for treatment of biofouling on mobile marine equipment are described in Section 4.9 of this report. In the following section, we discuss measures that have been used specifically to manage biofouling in the aquaculture sector.

6.6.1 Anti-fouling coatings

Effectiveness

Marine aquaculture uses a range of anti-fouling coatings to reduce the build-up of biofouling on farm infrastructure (e.g., farm barges, cage pontoons), and in some cases finfish netting. Copper-based coatings are commonly used to reduce biofouling on salmon farm nets in

[23] http://www.thecodeofgoodpractice.co.uk/annex/annex-10-minimising-risks-in-well-boat-operations/minimising-the-risks#Section323

countries such as Norway and Australia (Braithwaite & McEvoy 2005, Guenther et al. 2010, MacLeod & Eriksen 2009). In New Zealand, anti-fouling coatings have been utilised predominantly by the salmon industry on marine structures. For example, anti-fouling coatings have been used on farm barges and sometimes netting (i.e., copper-based compounds on predator-exclusion netting). There are also commercial copper-based anti-fouling products available that can be incorporated into, or applied to, mooring and anchor lines to reduce biofouling[24]. However, many of the chemicals and heavy metals involved can be harmful to the environment, cultured organisms, and consumers (predators and humans) (Guardiola et al. 2012, IUCN 2007, MacLeod & Eriksen 2009) or favour biofouling by organisms tolerant to the biocides used in the coatings (Braithwaite et al. 2007, Guenther et al. 2010). Some coatings may have a lower concentration or slower leach rate of biocides to make them more suitable for use with aquaculture species, but this reduced efficacy can also mean that they have to be re-applied more frequently (MacLeod & Eriksen 2009).

Alternative products that rely on fouling-release (e.g., silicone elastomers) and self-polishing, or surface topographies have been proposed for aquaculture (Fitridge et al. 2012, Hodson et al. 1997, MacLeod & Eriksen 2009, Scardino & de Nys 2011). These products are better at meeting regulatory requirements concerning environmental contaminants and product safety than conventional coatings. Whilst the efficacy of low surface energy coatings is greatest under higher flow conditions, they may also facilitate removal of biofouling by cleaning (Fitridge et al. 2012). The use of air-bubble curtains in conjunction with fouling-release coatings has been suggested as a possible control method for aquaculture infrastructure (Scardino & de Nys 2011), as have certain colours for infrastructure (e.g., observed higher barnacle settlement on red and black substratum) and electrochemical anti-fouling technology[25]. However, their efficacy remains to be tested.

Natural anti-fouling products are also available for use with mooring ropes and materials, such as Lanolene-based (wool-derived lanolin) anti-fouling and anti-corrosion products for application to various marine rope and wire products[26].

Feasibility

A range of anti-fouling products already exists to reduce the build-up of biofouling on marine farm infrastructure and can be accessed within New Zealand or imported.

Cost of compliance

Use of anti-fouling products is expensive. New Zealand King Salmon estimates it uses an average of 20 l of anti-fouling coating per square meter of predator net, with an expected life time for the coating of ~4 years (New Zealand King Salmon 2011). Different types of predator net have been investigated by some companies (e.g., brass chainmail nets and Kaynemaile), but these have not been considered worth pursuing in New Zealand for a variety of reasons, including the unknown quantity of biocides released, difficulties with handling and cleaning, and their cost. New Zealand King Salmon has now eliminated use of anti-fouling on some of its farm sites through improved net design and more frequent cleaning and replacement of the predator nets (New Zealand King Salmon 2011). However, net changing does represent a significant cost to the industry, as it requires purchase of more nets and increases the risks of damage or loss of stock. It is also very labour and capital-intensive, requiring medium to large sized vessels and hydraulic cranes (Fitridge et al. 2012)

Expected rate of uptake

The New Zealand aquaculture industry discourages use of toxic anti-fouling coatings on structures used in production areas because of potential effects of the biocides on the environment, their products and their marketability (New Zealand King Salmon 2011). The Finfish Aquaculture Environmental Code of Practice states that chemical treatments on farms

[24] www.aquaguardboatpaint.com; http://www.flexabar-aquatech.com
[25] http://cordis.europa.eu/search/index.cfm?fuseaction=lib.document&DOC_LANG_ID=EN&DOC_ID=124722931&q=
[26] www.lanolene.com

shall be minimised, and where possible, farm structures should not be treated with chemicals (New Zealand Salmon Farmers Association 2007). As a consequence, the salmon farming industry is attempting to reduce its use of anti-fouling coatings in favour of other management practices for biofouling. The Greenshell™ mussel and oyster industries generally do not use anti-fouling coatings on mobile infrastructure.

6.6.2 Biological control

Various "biological control" methods have been tried for controlling biofouling communities (Fitridge et al. 2012). Enhanced densities of sea urchins, sea cucumbers, crabs, grazing fish (wrasses), anemones and various molluscs have been trialled as a means to reduce biofouling (Atalah et al. 2013, Fitridge et al. 2012).

Effectiveness

Trials of biological control as a means to control growth of biofouling on structures have had some success, but efficacy is highly variable (Atalah et al. 2013, Greene & Grizzle 2007).

Feasibility

This is a technology that is in development. Key challenges include sourcing and maintaining populations of grazers or other natural enemies in densities that will be effective at minimizing biofouling.

Cost of compliance

At present the methods are very labour intensive and, therefore, are likely to be expensive to implement.

Expected rate of uptake

Unlikely to be an attractive option for use in the short-term.

6.6.3 Manual cleaning

Regular, in situ cleaning of the outer predator nets is becoming more commonplace in New Zealand to remove biofouling, as it is internationally (Guenther et al. 2011). This may be done by high-pressure water-blasting or rotating brush systems operated by SCUBA divers or using Remotely Operated Vehicles (ROVs). Biofouling on inner finfish nets (typically not coated with anti-fouling compounds) is usually managed by lifting the nets regularly, allowing them to air-dry and then water-blasting them on-site before returning them to the water. For both types of cleaning, the biofouling removed from the nets is not collected or contained.

Physical cleaning of the nets does not remove all biofouling (Hodson et al. 1997), and can allow colonial organisms and species capable of vegetative growth to regenerate, as happens with the problematic hydroid, *Ectopleura larynx,* in the Norwegian salmon industry (Guenther et al. 2010).

When farms are moved locally between sites for fallowing, it is common practice to water-blast the predator nets in situ and de-foul submersed farm structures (e.g., by scraping) before the farm is moved. Although this does not remove all biofouling, it is not considered economically viable to remove the entire farm from the water to clean it before moving it locally (Mark Gillard, NZKS, pers. comm.).

Figure 6-4 Salmon farm workers raising and water-blasting inner finfish cage netting in the Marlborough Sounds (Photos: C. Woods, NIWA).

Farm practices are employed in some situations to reduce problematic biofouling (e.g., sinking of spat/seed lines to lower depths to avoid periods of heavy recruitment by blue mussels). During harvesting of Greenshell™ mussels biofouling organisms are cleaned from floats and backbone ropes using scrapers in accordance with industry Operator Management Practices. The material removed is returned to the sea in the consented farm area where the harvesting occurs and cleaned floats are turned over to expose the biofouling to the sun. Backbone lines also typically exposed out-of-water at this stage (Aquaculture New Zealand 2007). Such de-fouled and exposed infrastructure is usually left in place for at least 3 days before further use and mussel floats, ropes and anchor systems not required in the short-term are taken on-shore, washed down with freshwater and dried for at least 3 days prior movement to different areas.

Figure 6-5 Seeding of Greenshell™ mussel lines using previously cleaned and de-fouled backbone ropes and buoys in the Marlborough Sounds (Photos: C. Woods, NIWA).

Effectiveness

Manual methods for removal of biofouling are generally not effective at removing all risk. Fragments of colonial organisms or resistant stages of solitary organisms (e.g., spores) may not be treated effectively unless manual removal is complemented by other methods of treatment (e.g., desiccation, chemical disinfection, etc.).

Practices that return viable fouling organisms removed from the structures into the water at the site that they came from may contribute to subsequent fouling problems in the surrounding environment, particularly when there are potentially harmful marine organisms present in the biofouling. The preferred practice is to dispose of waste material to landfill, but this may only be practical for small structures that are defouled.

Feasibility

For equipment that can be removed easily from the sea, manual cleaning by high-pressure water-blasting (on land or vessel), followed by desiccation or disinfection (using detergents or other appropriate chemicals) is a practical option and should be considered before equipment is moved outside the local production area.

Cost of compliance

Manual removal of biofouling can be labour-intensive, but is generally a low cost approach to biofouling management.

Expected rate of uptake

Some form of manual cleaning / removal of biofouling is already undertaken in most aquaculture operations, particularly for sea-cage farming of finfish.

6.6.4 Chemical treatments

General, low cost options for treating marine equipment were reviewed in Section 4.9 of this document and summarised in Table 4-3. Many of these will also be applicable to equipment used in the aquaculture sector. In addition, a range of disinfectants is already used within finfish aquaculture for different applications (e.g., Appendix 3). Although the principal use for these is in reducing risks from pathogens, many will also have utility against harmful marine organisms.

Investigations into chemical methods for control of harmful marine organisms have generally suggested four toxicants for treating biofouling (Clearwater & Hickey 2003, Coutts & Forrest 2005, Denny 2008, Forrest et al. 2007b, le Blanc et al. 2007, Locke et al. 2009).

- Acetic acid.
- Hydrated lime (calcium hydroxide, as a suspension in water).
- Sodium hypochlorite (bleach), and
- Alkaline ammonia (as ammonium sulphate solution with calcium hydroxide added).

A summary of some of the findings of these studies is contained in Appendix 4.

Effectiveness

Acetic acid

Acetic acid has been employed with some success against a number of non-indigenous marine species. In experimental trials on fouling plates, single spray treatments of 5% acetic acid with an exposure time of 1 min removed 55% of biofouling species present and repeat sprayings at short exposure times achieved ~99% mortality of the colonial ascidian *Didemnun vexillum* (Piola et al. 2008, Piola et al. 2010). Spray treatments of acetic acid were more effective at removing biofouling than hydrated lime (calcium oxide) and hypochlorite (bleach) (Piola et al. 2008, Piola et al. 2010). In commercial aquaculture, spray treatments using 5% acetic acid are effective against some colonial ascidians (e.g., *Botryllus schlosseri, Botrylloides violaceus* and *Eudistoma elongatum*), but are not as effective for solitary ascidians (Carver et al. 2003, Forrest et al. 2007b, Morrisey et al. 2009).

Treatments using immersion in 0.2% acetic acid for 1 min substantially reduced the settlement of the problematic fouling hydroid, *Ectopleura larynx* and survival of adults (Guenther et al. 2011). At 2.0% concentration, settlement and survival was ≤ 10% of control levels. MPI recommend using immersion in 4% acetic acid/freshwater solution for 10 min as a sterilisation treatment for equipment. Rinsing afterwards is optional[27].

Acetic acid concentrations remain stable over time in the presence of organic matter, but may change during repeated use of treatment solutions. It is necessary to monitor the active concentration of the acid during use to ensure that effective levels are maintained (Forrest et al. 2007b). Acetic acid needs to be stored at > 17°C or in a partially diluted form (e.g., 50% solution) to avoid solidifying, and is hazardous to handle, being highly corrosive and creating a strong odour (Coutts & Forrest 2005).

Lime
At least two forms of lime have been used in biological control for aquaculture or fisheries purposes: quicklime (calcium oxide, CaO) and hydrated lime (calcium hydroxide, $Ca(OH)_2$) (which is produced by adding water to quicklime) (Locke et al. 2009). Hydrated lime is toxic to a variety of organisms, can alter the pH of seawater if used in large quantities and can be difficult to apply consistently as hydrated lime powder is insoluble and there can be impurities in treatment solutions (Piola et al. 2010). Spray treatments of hydrated lime were not effective at controlling the droplet tunicate, *Eudistoma elongatum*, on oyster racks or intertidal shorelines (Morrisey et al. 2009). High concentrations (10-20%) and longer exposure times (>6 h) remove most biofouling invertebrates from experimental surfaces (Piola et al. 2008).

Sodium hypochlorite (bleach) and calcium hypochlorite
Sodium hypochlorite (bleach) has been used as a possible treatment method for biofouling organisms (Coutts & Forrest 2005). Immersion of equipment for at least 12 h in concentrations > 200 $g.m^{-3}$ is effective against *Styela clava*, but is less effective against other fouling organisms, including slipper limpets (*Crepidula costata*), oysters (*Crassostrea gigas, Saccostrea cucullata*), tubeworms (*Pomatoceros terraenovae*), other ascidians (*Asterocarpa cerea*, *Styela plicata*), and some macroalgae (*Ecklonia radiata* and *Codium fragile*) (Coutts & Forrest 2005).

Spray treatments of bleach, at relatively high concentrations (20%), were effective at killing the ascidians *Ciona intestinalis* and *Botrylloides leachii*, but not bryozoan fouling organisms. Mussel (*Mytilus galloprovincialis planulatus*) mortality increased at concentrations of 1-10% after 6 h immersion. Concentrations >5%, dissolved the byssal threads used by mussels for attachment (Lewis & Dimas 2007).

High Test Hypochlorite (HTH) chlorine (calcium hypochlorite), commonly used as a pool sanitiser from dry powder form, was used by mussel farms during the eradication programme for the Asian kelp, *Undaria pinnatifida*, in Stewart Island to treat infested lines after harvest, followed by drying them in the sun before returning them to the water (Hunt et al. 2009). Backbone buoys were also sprayed with HTH chlorine before sun-drying. Large structures such as barges and mussel rafts were beached at low tide and wrapped in polythene plastic and HTH chlorine granules were added to the water contained within the plastic wrapping. This treatment reduced, but did not eliminate all *Undaria* gametophytes.

MPI suggests sterilising aquaculture equipment by soaking it in a 2% bleach/freshwater solution for 30 min[28].

The Washington Department of Fish and Wildlife recommend that fish transfer tanks be disinfected when used between watersheds using liquid chlorine bleach (20 ppm active ingredient solution; 30 ppm if water is noticeably dirty or discoloured).

The Scottish finfish CoP recommends that nets be immersed in bleach at a concentration of 1,000 $mg.l^{-1}$ for 6 h (or an alternative equally effective disinfectant at the appropriate

[27] http://www.biosecurity.govt.nz/files/pests/salt-freshwater/aquaculture-factsheet.pdf
[28] http://www.biosecurity.govt.nz/files/pests/salt-freshwater/aquaculture-factsheet.pdf

concentration) then rinsed with freshwater (see also Appendix 3). The solution must be agitated to ensure an even concentration of hypochlorite. If nets are very heavily fouled the concentration of sodium hypochlorite should be increased to ensure the presence of at least 5 $mg.l^{-1}$ active free chlorine after 6 h[29].

The biocidal effectiveness of bleach solutions declines rapidly in seawater as free available chlorine (FAC) reacts rapidly with bromide and dissolved organic matter, both of which occur in high concentrations in natural seawater (Coutts & Forrest 2005, Morrisey et al. 2009, Piola et al. 2010). Although measurable concentrations of FAC decline rapidly, the brominated oxidants and non-oxidising chlorine by-products can still have toxic effects on marine organisms (Goldman et al. 1979).

Alkaline ammonia
Spray treatments using an ammonium sulphate solution (ammonium concentration of 200 $mg.l^{-1}$) were not effective at controlling the ascidian, *Eudistoma elongatum,* on oyster racks or intertidal shorelines (Morrisey et al. 2009).

Disinfectants, detergents and biocides
MPI suggests use of the detergent Decon 90 as a sterilisation treatment for aquaculture equipment[30]. Decon 90 is an alkaline cleaning agent that is used in laboratory, medical and specialised industrial applications. The protocol recommended by MPI is to soak the equipment in a 2% Decon 90 detergent/freshwater solution for 30 min. Decon 90 is suitable for use on glassware, ceramics, rubbers, plastics, stainless steel and ferrous metals, but is not suitable for use on non-ferrous metals, notably aluminium and zinc, or on polycarbonate.

Virkon® is a broad range disinfectant that is used by the finfish industry to guard against transport of fish viruses, bacteria, fungi, and moulds. It is marketed as an effective disinfectant for hard surfaces associated with aquaculture, including vehicles (boats, trailers, autos, etc.), nets, boots, waders, dive suits, hoses, brushes, hard surfaces and other similar equipment. The primary active ingredients are potassium peroxymonosulphate (21.5%) and sodium chloride (1.5%). Two products are available internationally: Virkon®S and Virkon® Aquatic. They share the same active ingredients, but Virkon® Aquatic has been formulated for specific use in aquatic environments and does not contain dyes and perfumes[31]. Virkon® Aquatic does not currently appear to be approved for use in New Zealand, but Virkon®S is used widely as a disinfectant. Virkon® Aquatic is registered for use in aquaculture in the USA and Canada, whilst Virkon®S is no longer recommended for use in aquaculture in the USA[32].

The household cleaning products *Palmolive Original*™ (Palmolive) and *Dettol*™ (Dettol) can also be effective against biofouling on marine equipment that can be removed from the water (Dunmore et al. 2011). Immersion of marine equipment for 60 min in either 1% Dettol or 5% Palmolive killed all colonies of the ascidian, *Didemnum vexillum*, and was effective against a range of other biofouling organisms such as solitary and colonial ascidians, macroalgae and bryozoans and the gametophyte life stage of *Undaria pinnatifida* (Dunmore et al. 2011). Using hot water solutions (40°C) reduced the required immersion time to 10 min. The effectiveness of these methods could be enhanced by using warm water and by drying gear thoroughly after treatment (Appendix 3).

Feasibility and cost of compliance

A range of chemical treatments is available for different cleaning and sanitation purposes within the aquaculture industry. Specific guidance is needed for the industry to be able to select tools that are appropriate and cost-effective for different types of equipment and operations.

[29] http://www.thecodeofgoodpractice.co.uk/
[30] http://www.biosecurity.govt.nz/files/pests/salt-freshwater/aquaculture-factsheet.pdf
[31] http://www.wchemical.com/Assets/File/virkonAquatic_VsVirkonS.pdf
[32] http://www.wchemical.com/VIRKON-AQUATIC-P44C11.aspx

Expected rate of uptake

Decisions about the use of chemical treatments in aquaculture must balance efficacy, costs (including regulatory compliance costs), environmental impact and impacts on production and marketability of stock against the consequences of spread of harmful marine organisms. In general, there is a preference within the New Zealand industry to avoid use of chemicals that may affect production or market perceptions of the product.

Biosecurity management plans developed by the industry could incorporate more specific guidelines for cleaning of gear that detail the circumstances in which chemical disinfection is recommended. This could involve a staged approach relative to risk, with more stringent disinfection required for equipment that is likely to be moved outside the local growing region (see e.g., the staged approach recommended by the Scottish finfish CoP for treatment of well-boats, Section 6.2.5.2).

6.6.5 Encapsulation and wrapping

Encapsulation (defined in Section 3.10.3) has been used to treat biofouling assemblages on fixed and mobile structures (Coutts & Forrest 2005, Coutts & Forrest 2007).

Effectiveness

The effectiveness of encapsulation for removing biofouling depends on at least three factors.

- The integrity of the wrapping.
- The length of time that the wrap is able to be kept in place.
- Whether freshwater or chemicals are used inside the wrap to accelerate mortality (see Section 3.10.3 and Floerl et al. 2010).

Survivorship within the wraps can be variable. For example, survivorship of the fouling ascidian, *Ciona savignyi*, on surfaces of floating docks wrapped with polyethylene tarpaulins was as high as 33% after 18 days (Pool et al. 2013).

Feasibility and cost of compliance

The feasibility of encapsulation has been demonstrated for fixed structures like pontoons and wharf piles (Coutts & Forrest 2005), but it is a less practical option for equipment that can be removed from the water easily for treatment on land or that has a complex shape (e.g., nets and ropes).

Morrisey et al. (2009) considered that encapsulation of oyster racks was unlikely to be a feasible option for treating fouling on oyster leases because of the large area that must be encapsulated and the likelihood that the wrapping would be punctured by the sharp shells of the oysters.

Coutts and Forrest (2005) estimate the costs of wrapping floating pontoons at ~NZ$150 per 3 m x 3 m section, with around ⅔ of that being labour costs. Adding acetic acid or sodium hypochlorite solution to accelerate mortality would add an estimate NZ$10 or $35, respectively, per 3 m x 3 m section.

Expected rate of uptake

Although encapsulation can be a relatively low cost option for treating biofouling, its utility is greatest for structures and equipment that cannot be removed easily from the water (and which, therefore, are less likely to be moved and pose a risk of spreading potentially harmful organisms). Fouled structures that can be removed from the water are better treated by a combination of manual removal (e.g., high-pressure water-blasting), air-drying and/or chemical sterilisation (Coutts & Forrest 2005).

6.6.6 Air-drying / Desiccation

Removal of structures from seawater and exposing them to air and higher light levels can be a low cost and effective treatment option for some biofouling organisms.

Sanford Ltd have an internal policy of allowing aquaculture equipment to air-dry for 2 weeks following removal from the water and require it to be cleaned manually before it is moved to another farming region (Ted Cully, Sanford Ltd, pers. comm.). MPI recommends that marine equipment removed from the water should be allowed to "thoroughly air-dry", with care needed to ensure ropes and equipment are not laid out in a manner that prevents the surface from drying out[33].

The Scottish finfish CoP recommends that all removable items, including cage nets, should be cleaned and disinfected before being moved to another location. They also recommend a fallow period for the structures of at least four weeks before reuse.

Effectiveness

Marine taxa have a wide range of tolerances to aerial exposure so the efficacy of air-drying will vary among species and will depend on the duration of exposure. While some soft-bodied organisms die relatively quickly, other biofouling species are able to remain viable for many days. For example, gametophytes of the Asian kelp, *Undaria pinnatifida*, can remain viable for 2–3 days at 10°C, and for longer than 8 weeks under more humid conditions (Forrest & Blakemore 2006). The clubbed tunicate, *Styela clava*, can survive aerial exposure for up to 6 days depending on ambient temperature and humidity (Coutts & Forrest 2005). The bivalves *Mytilus galloprovincialis* and *Perna perna* are capable of surviving continuous aerial exposure for >7 days with almost no mortality (Branch & Steffani 2004). Large aggregations of biofouling can also retain moisture that allows small organisms to survive for long periods.

Because of this variability in tolerance, Hilliard et al. (2006) recommend that air drying of biofouling occur for 21 days or more to ensure all organisms die. Where equipment is limited and needs to be redeployed, this length of inactivity may make desiccation impractical.

There are also some biosecurity risks if fouled structures that have been dried are returned to the water without the fouling organisms being removed. Many macroalgae, including *U. pinnatifida*, are induced to release spores following periods of desiccation (Thompson 2004) so that there is a high risk of establishment if the dried algae are returned to the water.

Feasibility and cost of compliance

Air-drying is generally a cost-effective means of treating biofouling on mobile structures, as it requires little additional plant or labour to implement. Nevertheless, because of the amount of time required for air-drying to effect mortality of all biofouling, there may be significant opportunity costs if the structures or equipment need to be redeployed within 21 days. This may require purchase of additional structures to allow some redundancy so that there is no loss of production while recently removed structures are treated by air-drying.

6.6.7 Heat

Heat has been used to treat biofouling in a number of applications, but the temperature employed and duration of exposure needed to achieve 100% mortality will vary among species. For example, the temperature regimes required to effect 100% mortality in large (55–80 mm) mussels (*Perna canaliculus* and *Mytilus galloprovincialis*) were 20 min at 37.5°C and 10 min at 42.5°C, respectively (Piola & Hopkins 2012). Immersion of the gammarid amphipod, *Dikerogammarus villosus*, in 36°C water for 15 min caused 100% mortality, with almost immediate mortality occurring at >43°C (Stebbing et al. 2011). The Asian kelp, *Undaria pinnatifida*, has been treated on submerged surfaces by heating seawater to 70°C

[33] http://www.biosecurity.govt.nz/files/pests/salt-freshwater/aquaculture-factsheet.pdf

for 10 min (Wotton et al. 2004), or by steam sterilisation at temperatures ranging from 33°C to 50°C for <1 min (Blakemore & Forrest 2007).

Morrisey et al. (2009) tested the efficacy of a gas-fuelled (propane or LPG) weed burner (used to control terrestrial pest plants) and heated, sugar-based foam (also used for herbicide-free control of terrestrial weeds, application temperature of ~80°C) for treating the intertidal populations of the fouling ascidian, *Eudistoma elongatum*.

Blakemore and Forrest (2007) trialled a steam sterilisation device to treat biofouling on floating pontoons. The device delivered hot water, generated on board an attendant vessel by a hot water pressure cleaner, to a purpose-built diver-operated spray lance that had been fitted with a silicone cone seal. The cone (30 cm diam.) enclosed the area of pontoon to be treated. The system was able to deliver temperatures of up to 50°C after application for 1 min (Blakemore & Forrest 2007).

The Scottish finfish CoP recommends heat treatment as an alternative to use of sodium hypochlorite to remove biofouling from netting and other structures. The protocol for nets is immersion in hot water so that the entire net is subjected to a temperature of more than 65°C for at least 10 min[34].

Effectiveness

The effectiveness of heat treatment on biofouling organisms depends on being able to hold temperatures at an elevated level long enough to ensure complete mortality. Temperatures >50°C for longer than 1 min will be effective against most marine organisms (Blakemore & Forrest 2007). Organisms with hardened shells, such as oysters, may require more severe treatment conditions to achieve 100% mortality. For example, mature oysters (*Crassostrea gigas*) can survive brief (45 s) exposure to temperatures as high as 70°C (Nel et al. 1996).

The uniformity of the surface being treated affects heat dissipation so that complex surfaces or biofouling assemblages may be more difficult to treat in situ using heat. For example, Morrisey et al. (2009) found that heat treatments (weed burner and foam) were less effective for treating *Eudistoma elongatum* than acetic acid. This may have been because some colonies or parts of colonies were shielded by other organisms or the topography of the substratum, or because the heat did not penetrate far enough into the colonies to kill zooids on the underside. Rapid loss of heat was thought to explain the limited effectiveness of the foam treatment (Morrisey et al. 2009). Similar difficulties in maintaining high temperatures in situ were reported by Blakemore and Forrest (2007).

Feasibility and cost of compliance

Heat treatment is a feasible option for treating soft biofouling on fixed structures like pontoons (Blakemore & Forrest 2007). It is best suited for simple, uniform structures. On more complex surfaces, practical difficulties with maintaining the temperature at a high level in situ mean that only small areas can be treated at a time so that it can be very time consuming to treat large areas. Working underwater with pressurised heated water can also be very hazardous for divers.

Expected rate of uptake

Heat treatment is unlikely to be a practical option for equipment that can be removed from the water easily and treated on land using other methods (e.g., high-pressure water-blasting and air-drying).

[34] http://www.thecodeofgoodpractice.co.uk/

6.7 Available practices to reduce risk - biofouling on livestock and associated equipment

Physical removal is the preferred industry practice to remove biofouling from livestock and equipment associated with livestock transfer. In the Greenshell™ mussel industry, mechanical stripping, de-clumping, washing and sorting of mussels during re-seeding significantly reduces the biomass of biofouling that is transported with re-seed mussels onto new lines (Woods et al. 2012). Some biofouling organisms are able to survive this process. Organisms that have resistant microscopic stages or which can regenerate from small fragments are unlikely to be removed completely by manual or mechanical treatment.

6.7.1 Pressurised freshwater/seawater spraying

In Prince Edward Island, Canada, high-pressure water-blasting with seawater is used for short-term control of biofouling, particularly of problematic, soft ascidian species like *Ciona intestinalis*, *Botrylloides violaceus* and *Botryllus schlosseri*, but not the more robust *Styela clava*.

Effectiveness

Pressure water-blasting at ~700 psi is a cost-effective treatment to remove soft-bodied biofouling organisms (e.g., ascidians). It can be applied with minimal training, and does not have any observable effect on mussel quality when used on mussel lines (Arens et al. 2011). At higher pressures (≥2,000 psi for 2 s) water-blasting is effective at removing gametophytes of *Undaria pinnatifida* from shell substratum and dislodges biofouling material from fissures and crevices (Coutts & Forrest 2005). A disadvantage of high pressure water-blasting is that organisms capable of regeneration from fragments (e.g., *Didemnun vexillum*, Hopkins & Forrest 2008, Morris & Carman 2012) may be spread as a result of the generation of large numbers of fragments.

Feasibility and cost of compliance

Pressure spraying is a feasible, low cost method of treating some forms of biofouling on shellfish livestock, but is not 100% effective at removing potentially harmful organisms.

Expected rate of uptake

Pressure spraying could be implemented relatively easily in most farm operations.

6.7.2 Chemical treatments

Acetic acid

New Zealand Greenshell™ mussels, *Perna canaliculus*, appear to be less sensitive to acetic acid than many associated biofouling organisms, as long as they are rinsed after treatment (Forrest et al. 2007b). Immersion in 4-5% acetic acid for <1 min is effective against solitary ascidians such as *Styela clava* and *Ciona intestinalis*, but is not practical for use on blue mussel (*Mytilus edulis*) stock because of acid dilution by water from immersed mussel socks and some associated mussel mortality (Locke et al. 2009). Concentrations of 4-5% acetic acid are lethal to macroalgae (e.g., *Undaria pinnatifida*) and mussel spat and will cause some mortality of adult blue mussels, bryozoans, caprellid amphipods, and polychaetes at exposures between 15 s and 4 min (Forrest et al. 2007b, Paetzold et al. 2008). See also Section 6.6.4 for other limitations of using concentrated acetic acid.

Acetic acid is no longer used as a commercial treatment in Canada and has been replaced by high-pressure water-blasting with seawater to control harmful colonial ascidians.

Hydrated lime

Hydrated lime has been used in Canada to control predatory seastars on mussel seed (spat) and, more recently, to manage harmful ascidians (e.g., *Styela clava* and *Ciona intestinalis*) on mussel socks and other aquaculture structures. Immersion troughs (e.g., 4% hydrated lime solution for 1 min) or low-volume sprayers were used to apply the treatment (Locke et al. 2009).

Sodium hypochlorite
Immersion in 0.5% solution of sodium hypochlorite for 20 s removes the ascidian, *Didemnum vexillum*, from Greenshell™ mussel seed-stock while leaving the seed-mussels relatively unaffected (Denny 2008). Immersion in 6% sodium hydroxide also caused complete mortality of *Didemnum*, but other chemicals (calcium oxide (lime, CaO), sodium metasilicate (silicic acid, Na_2SiO_3) were relatively ineffective (Denny 2008).

Disinfectants, detergents and biocides
Immersion in 3% Virkon® for 30 s has been shown to reduce biomass of the fouling ascidian, *C. intestinalis,* on mussels by up to 89%. Mussel mortality was low, especially in solutions <3% (Paetzold & Davidson 2011). Immersion of equipment in 1% Virkon®S for 15 min results in 100% mortality of the non-indigenous amphipod (*Dikerogammarus villosus*) (Stebbing et al. 2011).

A range of chemical therapeutics has been trialled to treat shell-deforming spionid polychaetes that burrow into the shells of living molluscs like oysters, abalone and Greenshell™ mussels. These have included: potassium permanganate, methylene blue, metronidazole, dimetronidazole, praziquantel, malachite green, formalin, mebendazole, fenbendazole, levamisole, ivermectin, trichlorofon, febantel, pyrantel embonate, hydrogen peroxide and gentian violet (Lleonart et al. 2003). Treatment is usually administered through immersion, with the solution concentrations and the duration of treatment varied according to the efficacy of the biocide and its effects on the treated stock. For example, Bilbao et al. (2011) reported that a monthly regime of 3-day immersion of abalone (*Haliotis tuberculata coccinea*) in a 6 $ml.l^{-1}$ solution of mebendazole, a broad spectrum benzimidazole carbamate, reduced worm infestations by 99% and had minimal effects on growth and mortality of the abalone stock.

Effectiveness

A variety of chemical treatments has been tested to treat different 'hitchhiker' organisms on aquaculture livestock. Their effectiveness varies according to the type of organism being targeted and the concentration and duration of treatment.

Feasibility and cost of compliance

A detailed analysis of the cost and feasibility of the range of chemicals available to treat hitchhiker organisms on aquaculture stock is beyond the scope of this review. More detailed guidance is needed for the industry on safe choices for specific applications.

Expected rate of uptake

Key considerations in the use of chemicals to treat livestock will be their effect on the stock and its marketability. The New Zealand aquaculture industry has a preference for limited use of chemical therapeutics in production and this is viewed as one of its advantages in the global market (Forrest et al. 2011). The industry is likely to avoid use of any treatments that may be perceived in the market as detrimental to the quality of its products.

6.7.3 Air-drying

As described in Section 6.6.6, the variable tolerance of marine organisms to aerial exposure means that it will not be a practical treatment for all biofouling organisms. For example, short-term (40 h) exposure to air was not a reliable method for controlling ascidian fouling on socked mussel seed (LeBlanc et al. 2007).

For some hitchhiker organisms, however, air-drying can be an effective treatment. For example, mudworm (polychaete) infestations in the Pacific oyster (*Crassostrea gigas*) industry are typically managed through aerial exposure and desiccation (Handley 1997). Air drying has also been shown to be effective in controlling mudworm infestations in abalone (Lleonart et al. 2003). An exposure time of 2–4 h at ~16 °C and 64% humidity was recommended for treatment of recent infestations and produced no mortality of adult abalone. Blacklip abalone (*Haliotis rubra*) 40 mm in length were able to tolerate air drying for up to 11 h in these conditions, but exhibited reduced growth over the longer term (Lleonart et al. 2003). Although densities of mudworms were significantly reduced by air drying, it did not result in 100% mortality.

Effectiveness

As described in Section 6.6.6, the variable tolerance of marine organisms to aerial exposure means that it will not be a practical treatment for all biofouling organisms.

Feasibility and cost of compliance

Air drying is a feasible and cheap option for treating biofouling on bivalves such as mussels and oysters that generally have greater tolerance of periods of emersion that many soft-bodied biofouling organisms. Extended periods of exposure will, however, cause increased mortality of juvenile livestock and of more sensitive species of shellfish (e.g., abalone).

Expected rate of uptake

Uptake is likely only when it can be demonstrated that the exposure times required to effectively treat the hitchhiker organisms do not result in mortality or reduced growth of stock.

6.7.4 Heat

Effectiveness

Immersion of shellfish stock in hot water baths for short periods can be an effective treatment for some biofouling organisms. For example, mussels fouled with the Asian kelp, *Undaria pinnatifida*, tolerated immersion in water heated to 55°C for 5 s without significant mortality. The treatment effectively removed the kelp (Forrest & Blakemore 2006).

As described in Section 6.6.7, the effectiveness of heat treatment will vary according to the tolerance of species in the biofouling. Soft bodied organisms will be treated effectively at moderate temperatures (e.g., 30-40°C), but hard shelled organisms (e.g., barnacles and bivalve molluscs) and resistant stages will require hotter treatments (50-70°C) and, potentially, longer immersion times to be effective.

Feasibility and cost of compliance

The feasibility of heat treatment for removing biofouling from livestock will depend on the relative temperature tolerances of the biofouling and the livestock. It can be a cost-effective option for treating biofouling on bivalves that generally have greater tolerance of short term exposure to heat, but is likely to cause increased mortality to juveniles and more sensitive species of shellfish (e.g., abalone).

Expected rate of uptake

Uptake is likely only when it can be demonstrated that the immersion in hot water effectively treats the hitchhiker organisms, but does not result in mortality or reduced growth of stock.

6.7.5 Novel technologies

Coatings on shellfish, such as waxes, food grade oils, polyurethanes, and low surface energy coatings have been trialled overseas to prevent biofouling (Bakker et al. 2011, Fitridge et al. 2012).

Effectiveness

Cahill et al. (2012) tested the efficacy of various naturally produced chemicals (“allelochemicals”[35]) for use in Greenshell™ mussel culture to prevent ascidian biofouling. They concluded that radicicol, polygodial and ubiquinone-10 have potential for future development in antifoulant formulations, and that the latter two compounds have no adverse impacts on Greenshell™ mussels (Cahill et al. 2012). Synthetic compounds have also been tested for aquaculture application as antifoulants. For example, the catemine medetomidine has been found to inhibit barnacle cyprid settlement at non-lethal nanomolar concentrations (Dahlstrom et al. 2000) and to reduce larval mobility and interfere with larval settlement of the clubbed tunicate, *Styela clava* (Willis & Woods 2011).

Feasibility and cost of compliance

These technologies are in development and require further research and testing for greater commercial application.

Expected rate of uptake

The New Zealand aquaculture industry does not currently use inert barrier coatings to prevent biofouling development or to facilitate its removal from shellfish species. As these technologies are still in development they are unlikely to be used widely in the short-term.

6.8 Available practices to reduce risk - processing of product

Land-based processing plants require resource consents to discharge waste-water to sea or land. Trade waste consents are required to discharge to sewerage systems, whilst handling and disposal of wastes on finfish farms are also regulated. Controls on these activities for hygiene standards (including any residual biosecurity risk) can, therefore, be implemented by regional authorities to prevent release of potentially harmful marine organisms (macroscopic and microscopic).

There is a large amount of detailed information available on techniques for disinfection and treatment of waste-water from aquaculture facilities. For example, the OIE Aquatic Animal Health Code provides extensive information on the disinfection of aquaculture establishments (stock, plant and equipment)[36][37]. Commercial disinfection products such as Virkon® Aquatic and Virkon® S are readily available internationally with guidelines on their use for different applications[38][39].

Effectiveness and feasibility

Requiring applications for resource consents to consider the risks of transfer and escape of harmful marine organisms from processing facilities will encourage operators to develop appropriate mitigation measures as part of their operating procedures. As discussed above,

[35] Allelopathy is a biological phenomenon by which an organism produces one or more biochemicals (allelochemicals) as a subset of secondary metabolites that influence the growth, survival, and reproduction of other organisms. Allelochemicals can have beneficial (positive allelopathy) or detrimental (negative allelopathy) effects on the target organisms.

[36] http://www.oie.int/international-standard-setting/aquatic-code/access-online/

[37] http://www.oie.int/fileadmin/Home/eng/Health_standards/aahm/2010/1.1.03_DISINFECTION.pdf

[38] http://www2.dupont.com/DAHS_EMEA/en_GB/ahb/fish/key_tasks.html

[39] http://www.wchemical.com/VIRKON-AQUATIC-P44C11.aspx

there is already a range of useful information and products that will allow operators to develop effective mitigation measures for streams of solid and liquid waste.

Cost of compliance

Cost of uptake will depend on the extent to which any measures proposed to prevent escape of harmful marine organisms differ from existing hygiene and waste disposal practices at the plants. Industries involved in production of seafood products for human consumption are already required to implement hygiene protocols for food safety.

Expected rate of uptake

Uptake of any new measures will depend on the duration of existing consented activities and the time-frame for their renewal. It may be difficult to get uptake in the short-term for activities that have existing consents of extended duration (e.g., >5 years).

6.9 Available practices to reduce risk – contaminants of farm equipment

6.9.1 International measures

Many international commercial finfish farms and hatcheries implement disinfection procedures for equipment as standard practice to prevent the spread of microbial pathogens. Many of these procedures will also be useful in reducing the risk of transfer of larger harmful marine organisms. For example, DuPont recommend disinfection of personal protective clothing by rinsing with clean water and immersion in Virkon® Aquatic for 10 min before hanging to dry. For diving equipment they recommend physical removal of any organic debris by brushing, followed by immersion in Virkon® Aquatic solution for 20 min, and then rinsing with clean water. For harvesting plant and equipment they recommend cleaning thoroughly with Biosolve® Plus (an alkaline, multipurpose, heavy-duty cleaner and degreaser), rinsing with clean water and then disinfection with Virkon® Aquatic[40]. Virkon® Aquatic has been successfully tested and recommended for use against microbes, New Zealand mud snails and zebra/quagga mussels in treating field and hatchery gear[41][42]. In Ireland, Virkon® S is used as an equipment disinfectant[43].

The Maine Aquaculture Association Finfish Bay Management Agreement has Biosecurity Guidelines related to finfish farm diving equipment that are designed to combat the spread of ISAV[44], but which will also help prevent the spread of other potentially harmful organisms.

- Diver equipment shall be site-specific.
- If a diver must dive more than one site using the same gear, it is imperative that all gear is disinfected between sites. Specifically, gear should be disinfected after the last cage at the first site and allowed to air dry. At the second site, the gear should be disinfected prior to diving the first cage.
- Diver attendants shall wear designed site-specific rain gear and boots. This gear must be properly cleaned and disinfected after each use.
- The dive boat should be site-specific.

[40] http://www2.dupont.com/DAHS_EMEA/en_GB/ahb/fish/key_tasks.html
[41] http://www.webpages.uidaho.edu/nzms/word%20and%20pdf%20files/Abstracts%20PDF/Stockton,%20oral,%20Evaluation%20of%20Virkon%20Aquatic%20toxicity%20and%20application%20to%20disinfect%20invasive%20mollusk%20infested%20field%20and%20hatchery%20gear.pdf
[42] http://wdfw.wa.gov/publications/01490/wdfw01490.pdf
[43] http://www.agriculture.gov.ie/media/migration/fisheries/aquacultureforeshoremanagement/SeaLiceControlStrategy%20(2)%20230210.doc
[44] http://www.aphis.usda.gov/animal_health/animal_dis_spec/aquaculture/downloads/isa_standards.pdf

- Diver attendants should not handle feed on that day. If dive attendants must handle feed, they must comply with all proper disinfection procedures. Ideally, the site should have a separate feed and diving crew (see also similar requirements for disinfection of dive equipment contained in the Scottish finfish CoP[45]).

6.9.2 Domestic measures

Commercial marine salmon farms in New Zealand have existing biosecurity protocols for decontamination of equipment and gear that could be adapted to include more specific actions related to harmful marine organisms. These protocols should also cover organisations that service the industry and that work between farms (e.g., commercial dive companies).

The paua industry has identified biosecurity protocols from the Australian abalone industry that could be implemented in New Zealand. Treatment solutions comprising detergent and freshwater, alkaline cleaners (e.g., Diverfoam), chlorine-based compounds (e.g., bleach), quaternary ammonium compounds (QAC's, e.g., Verticide, SanitQuat®), and peracid compounds (e.g., Virkon®) are used by fisherman in Australia as a means of disinfecting equipment and dive gear to prevent the spread of the Abalone Viral Ganglioneuritis (AVG)[46].

Effectiveness

The risk of transporting potentially harmful organisms entangled with dive gear will be reduced by the common practice of washing scuba and snorkelling gear in freshwater and drying. Greater reduction in risk can be achieved using detergents and disinfectants that have been approved for use in fisheries and aquaculture.

Feasibility, costs of compliance and expected rate of uptake

As described above, commercial salmon farms have existing protocols for decontamination of equipment that could be extended to other sectors of the industry through established Codes of Practice. Decontamination of immersible equipment, including dive gear, can be achieved by relatively low-cost measures (e.g., washing and drying), but uptake will depend on how risk from this mode of infection is perceived within the industry.

6.10 Available practices to reduce risk – escape from land-based farms

In New Zealand, resource consents are required for water intake and discharge of waste-water to sea or land. Trade waste consents are required for discharge to sewerage systems. The focus of these consents is predominantly to mitigate potential impacts on the quality of the receiving waters (i.e., contaminants such as nitrogen and phosphorous, faecal microbiological indicators, suspended sediments/turbidity, etc.). There is currently limited consideration of the potential for release of harmful marine organisms in discharged water.

Methods used to treat the quality of water in intake and discharge streams may reduce the risk of transfer of some harmful marine organisms. Methods of treatment can include, but are not limited to:

- filtration with screens or media or cyclonic separators,
- ultra-violet (UV) irradiation,
- high power ultra-sound, ozonation,

[45] http://www.thecodeofgoodpractice.co.uk/
[46] Tasmanian Department of Primary Industries, Parks, Water and Environment
http://www.dpiw.tas.gov.au/inter.nsf/Attachments/VWAS-7QLU3X?open
http://www.dpiw.tas.gov.au/inter.nsf/WebPages/SCAN-6ZX7S5?open

- chemical and biocide disinfection, and
- hyper- and hyposalinity exposure (see the chapter on disinfection of aquaculture farms in the OIE Aquatic Animal Health Code[47]).

Waste-water may also be discharged into sewerage or wetland systems or re-used within the facility following treatment (i.e., recirculation systems).There is a large amount of information on treatments recommended for disinfection of wastewater streams from aquaculture (discussed in Section 6.8).

Approval from MPI is required before transferring brood stock to farms in New Zealand. Collection, transfer and disposal of aquaculture organisms from hatcheries and land-based facilities are regulated by MPI under the provisions of the Freshwater Fish Farming Regulations 1983 (the Regulations), made under the Fisheries Act 1996. Fish movements from sports fish hatcheries are regulated by provisions of Section 26ZM(2) of the Conservation Act 1987 (Morrisey et al. 2010).

When organisms are transferred to land-based farms from outside the region there is potential for such transfers to be regarded as ‘introductions’ and to apply ‘quarantine’ conditions on farm discharges (and any subsequent stock movements) to prevent escape. For example, the ICES (2005b) guidelines on farm discharges, require all effluents and waste to be treated for all harmful organisms, with any disinfectants used neutralised before release into the surrounding medium. Effluent treatment systems should also have fail-safe backup mechanisms to ensure continuous operation and complete containment[48]. Such guidelines are recommended in South Africa regarding stock enhancement of abalone from land-based hatcheries[49].

Effectiveness and feasibility

Existing approval processes for transfer of stock to and from land-based facilities and for discharge of waste to marine environments could be strengthened to require consideration of the risks of transfer and escape of harmful marine organisms. Risk management plans developed during the consent process should be effective at reducing risk, if implemented.

Cost of compliance

Costs of uptake will depend on the extent to which any measures proposed to prevent escape of harmful marine organisms differ from existing procedures for stock transfer, hygiene and waste disposal practices at the facilities.

Expected rate of uptake

Uptake of any new measures through resource consents will depend on the duration of existing consents and the time-frame for their renewal. It may be difficult to get uptake in the short-term for activities that already have consents for periods >5 years.

6.11 Available measures to reduce risk - deliberate or accidental release

Where deliberate release of marine organisms is planned, rigorous assessment of risk of the spread of associated organisms, before release, is recommended. Preece et al. (2000) recommended that stock enhancement initiatives should have “seeding codes of practice” that address the range of potential negative effects associated with reseeding and enhancement. Several Australian States and Territories have policies governing stock enhancement programmes. For example, Queensland’s fisheries management policy

[47] www.oie.int/fileadmin/Home/eng/Health.../1.1.03_DISINFECTION.pdf
[48] http://info.ices.dk/pubs/Miscellaneous/ICES%20ITMO%20CoP%202005%20appendix%20revised.pdf
[49] https://www.environment.gov.za/sites/default/files/gazetted_notices/mlra_draftguidelines_g31143gon657.pdf

requires stocking to be undertaken by Fish Stocking Groups operating under an approved Fish Stocking Management Plan with rigorous risk assessments.

In New Zealand, the aquaculture science group in MPI provides information and advice to help guide decisions around deliberate release and stock enhancement programmes. Juvenile paua used in reseeding trials by the Paua Industry Council Ltd are required to be tested for pathogens prior to leaving the land based hatcheries; to date no harmful organisms have been found[50]. The paua industry has existing Codes of Practice relating to stock movements which are monitored by MPI. Customary translocation practices (e.g., Pataka concept) have a good existing regulatory framework[51], but few existing provisions related to preventing the spread of hitchhiker organisms.

6.12 Marine aquaculture – summary of recommendations

There are potential biosecurity risks associated with a range of operations within the aquaculture industry that involve movement between regions or farms, including the harvesting and transfer of livestock, movement of vessels (trailered and non-trailered), cages and other farming equipment, diving, and processing of product. Because of the range of activities that have some element of risk, international best practice within the sector has been to develop over-arching industry CoPs that incorporate procedures for reducing risk in each type of operation.

As with other commercial vessels in New Zealand that operate under SSM, consideration should be given to development and maintenance of an auditable BMP for non-trailered vessels involved in the industry. Simple measures are available to reduce risks from trailered vessels and immersible equipment, diving equipment, anchors, etc. These include inspection, cleaning and drying of the vessel, trailer and equipment after each journey or trip, removing attached biofouling or entangled organisms and rinsing and drying hull compartments.

Sterilisation of equipment might not be feasible for some marine farming activities (e.g., movement of large salmon cages and transfer of mussel spat on frames). Further consideration and consultation with industry is necessary to identify a workable approach. Improved record-keeping of stock and equipment transfers would improve the ability to manage outbreaks of harmful marine organisms and could also provide product traceability, which industry could promote in its marketing materials. Industry training in the CoPs and independent audit will encourage greater uptake of best-practice procedures for reducing risk.

A requirement for biosecurity certification of hatcheries and wild spat could be justified because of potential to spread harmful organisms quickly to multiple locations. The practical feasibility and cost would depend on the nature of the measures, which require further investigation.

[50] http://www.searanching.org/program/documents/Cooper_,000.pdf
[51] http://www.fish.govt.nz/NR/rdonlyres/4C12BC8D-1CE8-4B14-AEEF-4AEBE4B82562/0/63585_MOF_CustomaryFishingManual.pdf

7 Sport and recreation pathway

Recreational and sporting activities can transport harmful marine organisms in a number of ways (Carlton 2001, Hewitt & Campbell 1999, Hewitt & Campbell 2010).

- **As biofouling** attached to wetted surfaces or 'niche' areas of vessel hulls, pontoons and mooring blocks.
- **Intentional transport of organisms** as bait, catch, enhancement of seafood stocks or aquarium specimens (note that the supply chain for aquaria, through the pet trade, is beyond the scope of this study).
- Through **uptake in seawater** used for ship-board operations, such as bilges, cooling water, catch or bait holding tanks, and ballast tanks (for example, on ski boats).
- **As contaminants** picked up unintentionally during deployment and retrieval of equipment, including anchors, chains, mooring ropes, trailers, diving and fishing gear.

The transport vectors in the domestic sport and recreation pathway include inter-regional movements of recreational vessels by sea or land. Other, associated equipment, including anchors and chains, surf boards, kayaks, fishing gear, live bait, catch and holding water, and diving equipment, may also be transported by sea, land or air. Equipment used for sporting events, such as diving platforms, floating pontoons and course markers are also sometimes moved around the country.

Activities related to recreational use of the seashore can carry associated risks of transfer of harmful organisms. These include the movement of sand (including dredge spoil) for beach nourishment and beach grooming. Moored swimming pontoons also represent a potential vector if moved.

7.1 Recreational vessels

Recreational vessels have been implicated in the introduction and secondary spread of a number of harmful species (Carlton & Scanlon 1985, Dromgoole 1975, Trowbridge 1998) including the Asian kelp, *Undaria pinnatifida* (Forrest et al. 2000, Hay 1990), and the clubbed tunicate, *Styela clava* (Goldstien et al. 2010, Gust et al. 2008, Lützen 1999).

Hayes (2002) identified and ranked possible ways in which small craft (fishing vessels, motor launches, yachts and trailered boats) could spread potentially harmful marine species. Among displacement vessels, biofouling, water retention and internal fouling of seawater and grey-water inlets, internal fouling of sonar tubes, and water and sediment retained in sewage-holding tanks were ranked as the main sources of risk. Among trailered vessels, the main risks were from transport of organisms in burley buckets and the retention of water and sediment in the anchor well and bilge pump.

Similarly, Acosta and Forrest (2009) used information from a panel of international experts to model the necessary steps in the process of introduction of a harmful marine organism in different parts of recreational vessels. The model identified the roles of external fouling of the wetted 'hull', fouling, sediment or water released from the deck, internal spaces, anchors and fishing/diving gear. The extent to which these components are important is situation-specific, and depends on attributes of the vessel, its location and the harmful organisms present.

Entanglement of plants and movement of larvae in live wells of trailered boats tend to be the most common means of transportation of freshwater pest species (Johnson et al. 2001, Rothlisberger et al. 2010). There have also been several accounts of the transport of harmful marine organisms by entanglement in boat anchors (e.g., the invasive alga, *Caulerpa* *taxifolia*: Meinesz et al. 1993) and by overland movement of trailered boats (e.g., *Undaria pinnatifida*: Hay 1990) (see also Figure 7-1). In marine environments, however, fouling of boat hulls and other submerged surfaces is likely to be the principal way in which problem species are transported by larger vessels such as yachts and large launches (i.e., those that are too big to trailer).

Figure 7-1. The non-indigenous bivalve, *Arcuatula senhousia*, entangled by its byssus threads on the transducer of a depth sounder of a trailered vessel (Photos: G. Inglis, NIWA)

Levels of fouling are typically much greater in marine environments than in freshwaters, and a greater variety of organisms is able to occupy this habitat. Also, a larger proportion of vessels tend to be moored permanently in marine waters and many of these are removed only for servicing and cleaning. Approximately 10% of the estimated 600,000 recreational vessels in New Zealand are kept in marinas or on permanent moorings (Maritime New Zealand 2008).

Permanent exposure to marine waters means that, without appropriate treatment and servicing, boats can develop substantial growths of fouling organisms on their hulls. Movement of heavily fouled boats from areas where problem species occur to areas where they do not is likely to pose the greatest risk to biosecurity.

7.1.1 International vessels

New Zealand currently has 14 ports of first arrival for private, non-commercial ('recreational') vessels from overseas: Auckland, Bluff, Dunedin (and Port Chalmers), Gisborne, Lyttelton, Napier, Nelson, New Plymouth, Opua, Picton, Tauranga, Timaru, Wellington and Whangarei[52]. Between 1998/1999 and 2009/2010, the total numbers of international vessels arriving in New Zealand ranged from 472 to 797 (Floerl et al. 2008), with the largest numbers

[52] http://www.biosecurity.govt.nz/regs/ships/ports-first-arrival, accessed 15/3/13.

clearing customs at the northern ports, particularly Opua and Auckland. In 2003-2004, 79% of vessels arriving from overseas were foreign owned (*n* = 757: NIWA, unpublished data) and in 2005-2007 68% were foreign owned (*n* = 129: Floerl et al. 2008). The majority (~90%) of arrivals occur between October and December and ~90% are of vessels <20 m long (Inglis et al. 2012).

The duration of visits to New Zealand by international recreational vessels varies from days to years. In a survey of 283 international recreational vessels that departed New Zealand in 2002-2003 (NIWA, unpublished data, reported in Inglis et al. 2012), the average duration of stay in New Zealand was 258 days (SE 14.4, range 3 – 1,339). Data for 2006 from the New Zealand Customs Service (reported in Inglis et al. 2012) showed an average stay in New Zealand of 309 days (SD 145.6) and an average stay in each location visited of 24 days (range 1.8 – 357).

The numbers of locations visited after arrival is similarly variable. Many international vessels travel to a range of marinas or other locations (including off-shore islands) while they are in New Zealand. In 2002-2003, international pleasure craft visited an average of 3.9 (range 2-29) different named locations during their stay in New Zealand (NIWA, unpublished data).

7.1.2 Vessel movements within New Zealand

Domestic movements of recreational vessels within New Zealand include both New Zealand-domiciled and international (foreign-based or New Zealand-based vessels returning from overseas) vessels. Domestic vessel movements can provide an effective means of dispersal of harmful organisms once they have arrived in the country (Floerl et al. 2009).

The number of recreational vessels based in New Zealand is not known accurately because there is no required registration of non-commercial craft. Since 2002, Maritime New Zealand has commissioned market research to track boat ownership and usage. The 2011 survey estimated the number of domestic recreational vessels at around 600,000 (Table 7-1), with the largest percentages being made up by trailered power boats (31%), trailered sailing boats (6%) and small craft, such as kayaks/canoes (27%) and dinghies (23%). Motor launches and keeled boats, which are likely to be moored in marinas or fixed moorings, collectively comprised about 10% of the owned vessels (Colmar Brunton Ltd 2011).

There are an estimated 12,918 marina berths in New Zealand, with just under half (49%) of these located in the Auckland region (Beca Infrastructure Ltd 2012). In total ~85% of the permanent berths and moorings for keeled yachts and motor launches are located in the north-east of the North Island, between the Bay of Islands and Tauranga (Hayden et al. 2009).

In 2006, one in three New Zealanders (~1.5 million) reported going out on a boat at least once a year (Maritime New Zealand 2008). In 2011, nearly seven in ten boat owners (68%) reported going boating five times or more each year, while around half (49%) went boating 11 times or more per year, and nearly a third (29%) did so more than 20 times per year (Colmar Brunton Ltd 2011). Owners of motor launches and keel yachts tended to go boating more frequently than owners of other vessel types (Colmar Brunton Ltd 2011). General patterns in the use of recreational vessels reported by Maritime New Zealand (2008) included an increasing popularity of trailered vessels relative to larger moored vessels. The voyage range of these smaller craft has increased as engine size and reliability increase and electronic navigational equipment becomes more common.

Table 7-1. Estimated number of recreational boats in New Zealand by type.

	Estimated number in New Zealand (2011)	Percentage of total
Trailered power boat	186,912	31%
Kayak/Canoe	163,364	27%
Dinghy	139,816	23%
Trailer Yacht/Small Sail Boat	36,794	6%
Motor launch	38,265	6%
Keel yacht	22,076	4%
Personal water craft (jetski)	13,246	2%
Total	**600,473**	

Source: Colmar Brunton Ltd (2011)

Based upon the numbers of vessels and their average annual usage, Maritime New Zealand (2008) estimated that the on-water activity of the recreational sector in New Zealand is at least twice that of the domestic commercial maritime sector. Recreational vessels of all types made an estimated at 3.9 million trips in the six months around summer of 2002 (when the estimated fleet size was 269,131) and 1.9 million trips in the six months around winter (Maritime New Zealand 2008). In summer, 41% of vessels made trips at least weekly, 35% monthly and 65% "occasionally". In winter the equivalent figures were 10%, 20% and 91%, respectively. The uncertainty around these estimates is probably large.

Most movements by recreational vessels tend to be short, day trips within the region in which they are domiciled. Of an estimated 30,000 yachts or launches removed from the water and cleaned in recognised hull-cleaning facilities in 2001, 89% had not moved outside their home region since their last clean (McClary & Nelligan 2001). Just over 7% of the vessels had come from, or travelled to, other regions of New Zealand since their previous clean. Similarly, Lacoursière-Roussel et al. (2012) reported that only 25% of recreational boaters they surveyed in Marlborough and Nelson regions had visited another marina in New Zealand in the preceding 6 months. Most voyages were within the local area. This is also in accordance with surveys of recreational boating done overseas. In California, for example, <25% of boats ever travel more than 100 km from their home marina (Johnson & Fernandez 2011).

Nevertheless, because of the numbers of recreational vessels in use within New Zealand, these relatively small proportions of the total number of vessels still represent a large number of inter-regional movements annually. NIWA used data from separate questionnaire surveys of the owners of moored yachts and the operators of 36 marinas and mooring facilities throughout New Zealand to estimate the potential numbers and distributions of movements of moored vessels in New Zealand (summarised by Hayden et al. 2009 and Floerl et al. 2009). These revealed a complex network of movements throughout the country, with a large number of trips occurring between different regions. For example, of the estimated 2,600 trips made annually by Northland vessels to other marinas or moorings, more than half (57%) were to locations in the Auckland region, 5% to the Bay of Plenty and ~5% to locations in the South Island (predominantly Nelson and Marlborough, Table 7-2). Similarly, more than 2,500 trips were estimated to occur annually from Auckland to other regions of New Zealand; in particular to Northland (1478), Tauranga (359) and Marlborough (334, Table 7-2).

Table 7-2. Estimated numbers of annual movements made by moored vessels to marinas and moorings outside their home port†.

	Destination										
Region of home port	**Northland**	**Auckland**	**Waikato**	**Bay of Plenty**	**Hawkes Bay**	**Wellington**	**Marlborough**	**Nelson**	**Canterbury**	**Otago**	**Total**
Northland	831	1489	17	120	3	10	35	38	10	42	2595
Auckland	1478	5197	218	359	5	41	334	115	45	1	7793
Waikato	18	218	176	74	0	0	3	1	1	0	491
Bay of Plenty	120	359	73	0	0	1	199	4	2	0	758
Hawkes Bay	3	5	0	0	0	0	18	1	0	0	27
Wellington	10	41	0	1	0	0	482	93	6	0	633
Marlborough	35	333	3	200	17	483	152	173	51	40	1487
Nelson	37	115	1	4	1	94	173	0	53	0	478
Canterbury	10	45	1	2	0	7	51	53	0	0	169
Otago	41	1	0	0	0	0	39	0	0	32	113

†Data on vessel movements were obtained from national surveys of moored domestic (*n* = 923 vessels) and international (*n* = 795) vessels undertaken by NIWA between 2002 and 2004 (see (Hayden et al. 2009) for a description). Estimates of the total numbers of movements were made by extrapolating the survey data to the total numbers of vessels domiciled in each location, obtained through surveys of the operators of 36 marinas and mooring facilities throughout New Zealand.

7.1.3 Biofouling

Hull biofouling is a risk with non-trailered vessels, such as yachts and motor launches that are moored within marine environments and removed only periodically for maintenance and cleaning. Biofouling can lead to the spread of harmful marine organisms either through passive (unintentional) discharge of reproductive or other viable organic material or through the intentional removal of biofouling through hull cleaning during which viable material enters the marine environment, survives and becomes established.

Of 182 yachts inspected after arriving in New Zealand from overseas during 2005-2007, 149 (82%) carried some biofouling organisms (Floerl et al. 2008). Most international yachts (~ 80%) had biofouling covering <5% of the hull and only a relatively small number (6 out of 149) had >30% cover. Yachts domiciled in New Zealand also show marked variation in the extent of biofouling on their hulls related to the frequency with which they are cleaned and their geographic location. For example, surveys of fouling on domestic vessels moored in Tutukaka Marina (Gust et al. 2008), Viaduct Harbour (Gust et al. 2005), Lyttelton (Gust et al. 2008), Waikawa (Forrest 2013) and Nelson (Forrest 2013) using the six point Level of Fouling (LoF) index described by Floerl et al. (2005) (see also Appendix 1 of the accompanying Part B report; Sinner et al. 2013), recorded 16%, 14%, 26%, 15%, 30% and 30% of vessels, respectively, with LoF scores >2 (i.e., >5% of the hull covered by fouling). The corresponding proportions of the surveyed vessels with extensive fouling (i.e., LoF >3 or more than 15% of the submerged surfaces fouled) were 5.8%, 10%, 18%, 16% and 10%.

7.1.4 Bilges and other water containing spaces

There is some published information that suggests there is a risk of entrainment of planktonic larvae of harmful organisms into bilges and other water-containing spaces on recreational vessels (see Darbyson et al. 2009b and Section 3.4.2). A Canadian study of the risks associated with bilge showed that 69% of recreational boats used for fishing had wells, holding tanks or buckets to keep catch in. Most owners dumped the water from these at sea but a few dumped it in port. Water in bait storage containers was usually dumped at sea (Darbyson et al. 2009b).

Studies of recreational boating in North American lakes found larvae of the introduced zebra mussel (*Dreissena polymorpha*) in all forms of water carried by boats inspected at public boat ramps, including live wells (containers for keeping bait or catch alive, sometimes with water pumped directly from outside the hull), bilges, bait buckets, and engine cooling water (Johnson et al. 2001). The probability of transport was particularly high for engine cooling water but the volume of water involved was relatively small. The largest numbers of larvae were transported in live wells (estimated to be 40–100 times more abundant than in other locations). The authors estimated, however, that dilution in receiving waters would greatly reduce the risk of establishing new populations by the introduction of larvae.

Macroscopic life stages, including adults, of harmful species may also be entrained if the intake is large enough and water is not screened. Material dropped onto the deck and washed into the bilge is likely to represent a relatively high risk of translocation. Even if these spaces do not contain free water once the boat is taken out of the water, they may remain damp enough for some organisms to survive (Sant et al. 1996, Schaffelke & Deane 2005).

Conditions (temperature, salinity, dissolved oxygen and presence of toxicants) in the small volumes of water transported in recreational boats are likely to be adverse for the survival of larvae (Johnson et al. 2001). For example, bilge water is often contaminated with fuel and water in bait and catch containers will contain high concentrations of toxic metabolites such as ammonia. Water trapped in the intake for engine cooling water, in contrast, will not be heated and may provide the best conditions for survival of propagules, although the volume involved is small.

7.1.5 Containment / contaminants

Freshwater pests (particularly macrophytes) are known to be spread by trailered boats through entanglement on the boat or associated equipment (trailers, anchors, chains, depth sounders, etc.) (Johnstone et al. 1985). Although there is limited information about the transport of marine organisms by trailered vessels, anecdotal evidence suggests there is also a real risk from this mode of transport (see Section 7.1).

Between 27 and 45% of vessels surveyed leaving freshwater lakes carried fragments of macrophytes with them (Johnstone et al. 1985, Rothlisberger et al. 2010), although most of these carried <5 g of material. Numerous aquatic and terrestrial organisms, including some species that are morphologically similar to known aquatic invasive species, were also collected in wash-down water from the hulls (bilges and other internal water-containing spaces were not sampled).

Contamination of equipment may also occur indirectly, via entanglement of macrophytes containing other organisms. In a survey of recreational boats and associated equipment at public boat ramps on a lake in Michigan, USA, dispersal of zebra mussels (*Dreissena polymorpha*) by boats occurred primarily by attachment on macrophytes entangled on boat trailers or anchors (5.3% and 0.9% of departing boats, respectively), rather than by direct attachment to boats (Johnson et al. 2001). Combining these data with estimates of survival in air and reported boater destinations, the authors estimated that up to 0.12% of the trailered boats departing these access sites delivered live adult mussels to inland waters solely by transport on entangled macrophytes. Lowest risk groups were those who only boat on one water body. Better identification and characterisation of these different risk groups may allow better targeting of management measures.

There is a further risk of translocation of harmful organisms through entanglement of macrophytes, other biological material and sediments with anchors and chains. These contaminants may subsequently be transported in damp, shaded parts of a boat, such as anchor lockers, where they may remain viable for up to several days (Darbyson et al. 2009b, Johnson et al. 2001).

West et al. (2007) examined the risk of translocation of the invasive alga, *Caulerpa taxifolia*, by anchors, ropes and chains of recreational boats in eastern Australia. Experimental simulations of anchor deployments indicated that fragments of the alga were removed by the anchor in 82% of deployments. Rock and sand anchors removed similar sized clumps while chains removed larger clumps than ropes. Bigger clumps showed longer viability once removed from the water, particularly in damp, shaded conditions such as under piles of rope. No clump of any size showed viability after three days, but in another study, Carlton and Scanlon (1985) found that *C. taxifolia* could survive for up to 10 d in cool, damp conditions.

7.2 Structures – pontoons and moorings

There are at least 45 coastal marinas in New Zealand, containing pontoon, piles and swing moorings. In addition, there are large numbers of swing mooring distributed around the coast. Hayden et al. (2009) estimated the number of swing or pile moorings at around 10,000 nationwide, but the actual number is likely to be closer to 13,000. Twenty-seven of the 45 marinas in New Zealand are located on the eastern coastlines of the Northland, Auckland, Waikato and Bay of Plenty regions, with a combined total of 9,332 marina berths (~72% of the country’s total; Beca Infrastructure Ltd 2012).

In general, moorings occupy seabed and, therefore, require approval under the Resource Management Act 1991. There is, however, some variation in the requirements within different regions of New Zealand. The coastal plans of many regional authorities specify designated mooring management areas where swing moorings are a permitted activity. Outside of these areas, requests to establish a mooring require individual consents. In Tasman most moorings are not currently consented, but the relevant rules are under review and it is expected that consent will be required from 2014 (Steve Hainstock, Tasman District Council Harbourmaster, pers. comm.).

There are, currently no national or regional marine industry standards that guide the mooring industry in New Zealand (Northland Regional Council 2012). Consequently, there is considerable variability between councils and contractors in the requirements for design, inspection and maintenance. Ownership of moorings also varies between regions, with some ownership by regional authorities, private ownership (or consent ownership) of space and/or private ownership of mooring equipment (Northland Regional Council 2012). The numbers of swing moorings also varies among regions. Auckland Council administers 78 Mooring Management Areas incorporating around 4,300 individual swing moorings (Beca Infrastructure Ltd 2012). Nelson City Council manages ca. 50 moorings and ~3,000 moorings are present in the Marlborough Sounds (Piola & Forrest 2009).

Where swing moorings are consented, the consents may require the removal of the block at the end of its life, but in practice most probably are abandoned in situ (Steve Hainstock, pers. comm.). Some blocks are home-made from concrete or scrap steel and of little economic value so there is little incentive to recover and reuse. Council-standard blocks may, however, cost up to NZ$3,000 and may be recovered and used elsewhere, during which they may spend varying amounts of time out of the water.

7.2.1 Modes of infection

Pontoons, moorings and piles do not represent a risk for translocation of potentially harmful organisms unless they are moved and fouling organisms on them are able to survive the translocation. They may, however, provide a source of fouling organisms for vessels moored on them or nearby.

Swing moorings are potentially more mobile and may pose greater biosecurity risks than marina berths (Piola & Forrest 2009). Nevertheless, pontoons (or "floating docks"), including those used in marinas, are easily moved (by towing) and are occasionally translocated to other regions.

Swing moorings have lower costs associated with them than marina berths and may, therefore, be used by poorly maintained vessels - either active boats whose owners do not regularly antifoul and renew the anti-fouling coating or inactive boats for which a swing mooring represents the cheapest available long-term parking. Several such inactive vessels became heavily fouled with *Didemnum vexillum* following its initial incursion in Shakespeare Bay near Picton (Coutts & Forrest 2007). Many swing moorings are in isolated locations, promoting an 'out of sight, out of mind' attitude and making them more difficult for the managing authority to monitor. There are also a number of unauthorised moorings in some harbours (Piola & Forrest 2009).

7.3 Recreational fishing equipment, including live bait and catch

An estimated 19% of the New Zealand population fishes at least once a year, of which 3% may be considered avid fishers and likely to have their own boats (data provided by National Research Bureau (NRB) to NIWA[53]). The NRB data contain information on where fishers live and where they fish, which may allow some assessment of the relative numbers of fishing trips that take place outside the fishers' home region. These data, collected in a 2011/12 survey, were not available to the project team at the time of writing, but the findings are expected to be released by MPI in June 2013[54].

7.3.1 Modes of infection

Recreational fishing provides a pathway for the movement of harmful marine organisms through contamination of gear (rods, lines and hooks, dredges, traps, harpoons and spear-

[53] See http://www.nrb.co.nz/fishingsurvey.php
[54] http://www.fish.govt.nz/en-nz/Recreational/Recreational+Research+Programme.htm

guns, etc.), live bait, catch and water used for holding bait or catch. Vessels used for fishing, including kayaks, yachts, motor launches and jet skis, may also provide a pathway for spread of harmful organisms (see Section 7.1 on Recreational Vessels, above).

Most recreational fishing gear is not deployed long enough to become fouled but may pick up harmful organisms by chance from substrata such as the seabed and wharf piles. Recovery of lost gear, including nets, dredges and traps, provides a small risk of transfer of fouling or other harmful marine species.

Dredges, such as those used to collect scallops, present a risk of translocating benthic organisms and sediments if not cleaned prior to relocation.

Live bait products are specifically intended to be released into the coastal environment. In the USA, bait is often packed in seaweed which may be dumped into local waters together with any associated organisms (Weigle et al. 2005). The European green crab (*Carcinus maenas*) and the alga *Codium fragile* spp. *tomentosoides* are believed to have been introduced to the west coast of the United States in seaweed used to pack bait worms (Lau, 1995, cited in Weigle et al. 2005). It is unclear if this practice occurs in New Zealand. Unlike the USA and Australia, we know of no established commercial suppliers of marine live bait products in New Zealand. Recreational fishermen in New Zealand may use live shellfish (crustaceans and molluscs), algae, worms and small fish as bait, but these are typically captured by the fishermen prior to travelling to the fishing grounds for their target species. Fish, shellfish and other organisms caught as live bait may be kept alive in holding tanks or seawater containers on-board the vessel and transported to the fishing grounds.

There is also a risk of introduction of harmful species via the medium in which the bait is held. In a survey of live-bait traders in Massachusetts (Weigle et al. 2005), more than half of those surveyed who reported discharging water from holding tanks directly to natural water bodies did so without treating it first. A high proportion of respondents had observed non-target species (such as crustaceans, molluscs and worms) associated with imported non-local bait species. However, the live bait industry apparently imported only a small number of different taxa, and many were processed or indigenous to local waters.

A review of changes in bait fish and bait use in New Zealand has recently been completed as part of a review of the Import Health Standard. This has shown a doubling of the annual amount of bait imported, together with an increase in the number of species imported and the number of sources, between 2008 and 2012 (Ron Blackwell, MPI, pers. comm.). However, import of viable organisms to New Zealand for use as bait is excluded by the *Import Health Standard For Fish Food and Fish Bait from all Countries*[55], with the exception of viable brine shrimps *Artemia salina* and *A. fransiscana* (Crustacea: Branchiopoda).

There are few restrictions on the translocation and release of catch by recreational fishers (other than for species declared Unwanted Organisms under the Biosecurity Act 1993) (Richard Fraser, MPI, pers. comm.). Fishers may target introduced species such as fish, paddle crabs and other crustaceans that are valued for human consumption or, alternatively, capture and move them for use as bait. The seasquirt, *Pyura doppelgangera*, first recorded in New Zealand near Cape Maria van Diemen in 2007[56], is commonly used as bait by rock fishermen in its native Australia (Dakin 1952). Anecdotal information suggests that commercial crab fishermen are catching the introduced Japanese lady crab (*Charybdis japonica*) in and around Whangarei Harbour and recreational fishers may target this species too (*C. japonica* also occurs in the Waitemata Harbour and nearby harbours). The eastern Australian green or greasy-back prawn (*Metapenaeus bennettae*) was recorded for the first time in New Zealand in the Waitemata Harbour in 2009 (NIWA, unpublished data collected as part of the Marine High Risk Surveillance on behalf of MPI under contract no. 12099). This

[55]http://www.biosecurity.govt.nz/imports/animals/standards/fisfooic.all.htm, accessed 4 April 2013.
[56]http://www.biosecurity.govt.nz/pests/Pyura, accessed 4 April 2013.

species is fished commercially in Australia[57]. Its distribution in the Waitemata Harbour has subsequently expanded and it has also been recorded in Whangarei Harbour and will presumably eventually be targeted by recreational, and possibly commercial, fishers.

7.4 Diving equipment

A 2009 survey of participation in sport and recreational activities within New Zealand estimated that around 121,000 people (~3% of the adult population) went diving/scuba diving in the preceding 12 months (Sport and Recreation New Zealand 2009). Rates of participation tend to be greatest in north-eastern New Zealand, in the Auckland and Northland regions, with only a small proportion of divers (~3%) belonging to organised clubs or associations (UMR Research Ltd 2006).

7.4.1 Modes of infection

There have been no direct studies of the risks that divers pose in the spread of harmful marine organisms or their propagules. Anecdotal observations suggest that they may transport organisms through entanglement in diving equipment, with water inside buoyancy compensators, trapped in catch bags or other equipment or as spores or fragments attached to wetsuits (Carlton 2001).

7.5 Marine aquaria

More than 150 species of vertebrates, invertebrates, plants and microorganisms (including pathogens) have invaded natural water bodies worldwide via the aquarium trade and ornamental aquaculture (Padilla & Williams 2004). Well-known marine examples include the macroalga, *Caulerpa taxifolia* (introduced to parts of the Mediterranean, Australia and California; Zaleski & Murray 2006), and the lionfish, *Pterois volitans* (introduced to the east coast of the USA; Whitfield et al. 2002). Sixteen species of marine fish imported for the aquarium trade in the USA have been reported from 32 locations in the western Atlantic coast (Semmens et al. 2004).

Semmens et al. (2004) used information on international shipping movements and marine fish imports to assess the relative risks of these two pathways as contributors to the populations of non-indigenous fishes on the reefs of southeast Florida. They concluded that recorded introductions were likely the result of aquarium releases. Duggan et al. (2006) identified a positive relationship between the frequency of occurrence of freshwater aquarium fish in shops in Canada and the United States and the likelihood of introduction and establishment in the wild. The same may also be true of marine aquarium species, as suggested by the evidence from Florida (Semmens et al. 2004).

The risk of introductions of harmful marine organisms to natural waterways via the aquarium trade is significant, as evidenced by experience in the United States with marine organisms, and by experience with freshwater aquarium species in New Zealand. However, there have been no detailed studies of the marine ornamental pathway in New Zealand or the likelihood of survival in New Zealand waters of species introduced through this pathway. Import of marine organisms for the aquarium trade in New Zealand is managed through the *Import Health Standard for Ornamental Fish and Marine Invertebrates from All Countries*[58], which includes a list of species permitted to be imported. Once in New Zealand, however, there is little ability to control the movement or release of aquarium organisms, either deliberate or accidental. The list of species approved for import has evolved over time and it is likely that some species no longer approved are already present in New Zealand. McDowall (2004) cites the examples of the freshwater goldfish (*Carassius auratus*), which is not on the approved list but has been in New Zealand for >100 years and is widespread in the wild, and a number of other species freshwater fish that are known or suspected to have established

[57] http://www.dpi.nsw.gov.au/__data/assets/pdf_file/,0005/375899/Greentail-Prawn.pdf, accessed 4 April 2013.
[58] http://www.biosecurity.govt.nz/imports/animals/standards/fisornic.all.htm, accessed 4 April 2013.

wild populations. The marine alga *Caulerpa taxifolia*, listed as an Unwanted Organism under the Biosecurity Act 1993, has been found in an aquarium shop and a public aquarium in Auckland, and the related and also invasive *C. racemosa* has been found in an aquarium shop in Nelson (Smith et al. 2010). Although most salt water hobbyists in New Zealand appear to keep tropical species, there are some who prefer cold water species from New Zealand and stock their aquaria by collecting specimens themselves. There is, therefore, a risk that established non-indigenous species could be collected and kept.

7.5.1 Modes of infection

Non-indigenous aquarium species may enter natural water bodies through deliberate release, escape from aquaria or aquaculture facilities, drainage of water from domestic or public aquaria, or disposal of water in which specimens have been transported (Padilla & Williams 2004). Reasons for deliberate release include stocking for recreational fishing, disposal of unwanted stock and ritualistic release during religious practices.

In the USA, Jensen et al. (2006) found that 30% of freshwater aquarists and pond-keepers surveyed had unwanted specimens during the previous three years and, of this 30%, 18% dealt with the problem by releasing fish, plants, freshwater crayfish, snails or turtles into natural waterways (a total of 43 releases). Of the 82% who chose not to release their unwanted specimens, >90% did so because they felt it to be unethical, 83% not good for the environment and 46% because they knew it to be illegal. Most (62%) chose to resell their specimens or return them to the point of purchase. Among all of the people surveyed, only 20% were aware of laws or regulations relating to the release of aquarium or pond species.

A survey of businesses in the Australian marine aquarium trade found that retailers generally dispose of unwanted stock by freezing the specimen and putting it out for municipal waste collection (Morrisey et al. 2011). Wholesalers, some of whom were also importers, either froze or incinerated unwanted, dead or diseased stock. Some specimens were put into municipal sewers (whether dead or alive was not stated) or used as food for other stock. Quarantine material was either frozen and sent to the Australian Quarantine and Inspection Service (AQIS) for disposal or incinerated. Retailers disposed of the water in which animals and plants were received from suppliers, or held in the store, by discharging it to the sewer, incorporating it into the store's aquarium system, sterilizing it (by unspecified methods), or bagging it and putting it out for municipal waste collection. One retailer was allowing the water to discharge to their car park and evaporate. In accordance with AQIS guidelines, three of the wholesalers treated water and others discharged it to the sewer. Some incorporated it into their own aquarium system; this was presumably water that had not been used to transport or hold quarantine material.

Responses to the survey of Australian traders suggested that understanding of the environmental hazards of releasing marine organisms is poor (Morrisey et al. 2007). For example, the only harmful marine organism that most interviewees were familiar with was *Caulerpa taxifolia* and this familiarity derived from perceived penalties for selling it rather than knowledge of its undesirable effects if released. Overall, the retail and wholesale trade in marine aquarium species in Australia was not well-informed about marine biosecurity and was confused about what the issues and their responsibilities are. More encouragingly, it seems that the trade would be receptive to proposals for it to become involved in managing risk if measures were appropriate and acceptable.

History suggests that awareness of the adverse effects of releasing aquarium specimens is also poor among members of the general public and that accidental or intentional releases from this source are likely to occur. This is borne out by the examples of species that have already established populations in natural waterways in New Zealand, such as goldfish, koi carp (*Cyprinus carpio*), gambusia (*Gambusia affinis*) and red-eared slider turtles (*Trachemys scripta*) (Kikillus et al. 2012, McDowall 2004). Unlike Australia, where on-line trading of livestock is prohibited on the most popular internet trading site (eBay), internet trading of aquarium livestock is permitted on TradeMe in New Zealand and appears to be common

(Derraik & Phillips 2010, Kikillus et al. 2012). This provides an easily accessible pathway for translocation of potential and known harmful organisms that is difficult to regulate.

7.6 Beach management

Material collected during beach grooming and beach clean-up campaigns is generally sent to landfill or to be recycled (in the case of large items such as tyres and scrap metal) (Lindsay Vaughan and Paul Sheldon, Tasman District Council, Karen Lee and Richard Popenhagen, Nelson City Council, Janice Gravett, Department of Conservation, pers. comm.). Material from grooming of beaches in the Auckland Region is sent to a recycling / recovery company (Scott Speed, Auckland Council, pers. comm.). Consequently, the risk of translocation of harmful organisms through disposal of beach-groomed material is small.

Material used in beach nourishment is likely to be sourced locally because of the cost of transport and because resource consent may not be required if material is moved only small distances (such as from one end of a beach to the other). In such situations, the biosecurity risks involved are likely to be very small. For example, renourishment of Tahunanui Beach in Nelson in 2004 involved taking material from a growing sand spit at one end of the beach and using it renourish the eroding eastern end of the beach (Morrisey 2003). Material was moved by truck over several hundred metres and would be taken in future on an "as-needs" basis in volumes of 500-10,000 m^3. In this particular case, despite the small distance between source and deposition site, Nelson City Council determined that resource consent was required.

Other renourishment work may involve movement of material over larger distances, such as from Golden Bay to Oriental Parade, Wellington, for which 22,000 t of sand was transferred[59]. The resource consent for the beach renourishment programmes at Freiberg, Oriental and Eastern Beaches (Consent Certificate no. WGN020036) includes a requirement for the consent holder (Wellington City Council) to monitor for adverse effects on marine ecology but there is no specific mention of harmful marine organisms.

Movement of material for renourishment over small distances is allowed in the Auckland Region as long as the material comes from the same coastal circulation cell, which is likely to minimise the risk of dispersal of non-indigenous species (Scott Speed, Auckland Council, pers. comm.). Where material is transported over larger distances, it is required to be free of waste and contaminants and to have similar physical characteristics to the renourishment site. Harmful organisms, or non-indigenous species not already present at the renourishment site would be considered a biological contaminant. In practice, most material used for renourishment is taken from a single source at Pakiri Beach, which is considered to be low-risk for harmful organisms, being an exposed ocean beach away from ports or marinas. Any alternative source of material would require a permit for extraction and biosecurity risk would likely be considered during the consenting process (Scott Speed, pers. comm.).

7.7 Available practices to reduce risk – biofouling on recreational vessels

7.7.1 International measures

In November 2012, the Marine Environment Protection Committee of the International Maritime Organization adopted guidelines for "*Minimizing the Transfer of Invasive Aquatic Species as Biofouling (hull fouling) for Recreational Craft*" (International Maritime Organization 2012). The guidance is directed at all owners and operators of recreational craft <24 m in length, including trailered craft, and contains information on appropriate use of anti-fouling coatings, and cleaning of hull and niche areas.

For non-trailered craft, the guidelines recommend the following measures.

[59] See http://www.tonkin.co.nz/water_coast&ports.htm, accessed 11 April 2013.

- Seeking expert advice on the choice of anti-fouling coatings for the vessel hull and niche areas to ensure they are effective for the planned use of the vessel,
- In-water inspection before a change in operating profile (such as a long-distance trip or after a period of inactivity) to evaluate levels of biofouling,
- Haul-out and cleaning of the vessel at least once per year in a land-based facility, where the waste can be captured effectively for proper disposal,
- In-water cleaning to remove light fouling only (e.g., slime layer) where such cleaning does not contravene local water quality regulations, and
- Maintaining a record of biofouling management on the craft, including details of the anti-fouling systems used and any inspection or cleaning that has been done (International Maritime Organization 2012).

For trailered craft, five measures were recommended in the IMO guidelines.

- Inspection, cleaning and drying of gear and equipment after each journey or trip.
- Removing attached biofouling (e.g., seaweeds, barnacles, mussels) from the craft, gear, equipment and trailer;
- Draining hull compartments, pipework and outboard engines;
- Rinsing the craft inside and out with freshwater and, if possible, drying all areas before moving; and
- Disposing of biofouling and waste-water ashore where it cannot drain back into the water or drains.

7.7.2 Australia

The Commonwealth Government of Australia released a guidance document to assist recreational vessel owners manage the risk of spreading potentially harmful marine organisms in biofouling and through other means (Commonwealth of Australia 2009b). In general, the recommendations for trailered and non-trailered vessel mirror those in the IMO guidelines described above (International Maritime Organization 2012).

For non-trailered vessels, the guidelines suggested eight complementary measures:

- Removing biofouling as soon as possible at a licensed vessel maintenance facility if the vessel has well-established biofouling.
- Regular removal of the slime layer with a soft cloth to prevent build-up of heavy fouling (if permitted under local regulations for in-water cleaning).
- Regular checking and cleaning of propellers and other unpainted underwater fittings.
- Regular treatment of internal seawater systems with freshwater or an approved treatment.
- Monthly inspection of hulls if the vessel is moored for long periods.
- Inspection, cleaning and drying of equipment prior to moving to a new location.

- Ensuring the boat hull is clean before proceeding to a new location.
- Notifying local authorities of any suspected harmful organisms (International Maritime Organization 2012).

Five measures were recommended for trailered vessels.

- Checking for, and removing entangled or attached biological matter from the boat and trailer.
- Checking the outboard and hull fixtures for water that could harbour potentially harmful organisms.
- Rinsing the boat inside and out with freshwater, draining and, if possible, allowing it to dry before moving to another location within 48 h.
- Regularly removing slime from the hull to prevent build-up of secondary biofouling.
- Disposing of any biological material, including known harmful organisms to bins or landfill so that it cannot be returned to the water.

The guidelines also contain recommendations for selection and application of anti-fouling coatings and disposal of waste and effluent.

7.7.3 Management at the border

The approach taken by the New Zealand Government to manage biofouling on vessels entering New Zealand waters from overseas (including recreational vessels) is described in Section 3.9.2 of this report and Section 3 of the companion (Part B) report. At present, yachts and other pleasure craft are requested to clean biofouling from their hulls and niche areas prior to departing for New Zealand and to flush any places where seawater is retained such as internal water spaces, anchor wells and cockpit areas. Vessels that are unable to be cleaned prior to departure for New Zealand, should be cleaned within four days of arrival, particularly if they plan to stay for more than two weeks.

7.7.4 Management of biofouling on domestic or short regional voyages

Several recent studies have reviewed options available in New Zealand for managing biofouling on pleasure craft (Floerl et al. 2010, Inglis et al. 2012, Piola & Forrest 2009). Two complementary approaches have been considered.

- Education of vessel owners on appropriate use and maintenance of anti-fouling coatings for their vessel.
- Regular cleaning of biofouling from submerged surfaces in:
  - haul-out (shore-based) facilities, or
  - by in-water cleaning using a range of methods.

7.7.5 Education / social marketing campaigns

Educational materials (“outreach”) have been developed by MPI to encourage better hull husbandry within the recreational boating sector in general[60] and for vessels planning to travel to Fiordland[61]. They include information about the problem of marine invasive species and recommendations for reducing biofouling through improved use of anti-fouling coatings

[60] http://www.biosecurity.govt.nz/biosec/camp-acts/marine/cleaning
[61] http://www.biosecurity.govt.nz/files/pests/surv-mgmt/marine-fiordland-resource-cards.pdf

and regular cleaning. Key messages include the need for regular anti-fouling and a 'clean before you go' approach before sailing to another region.

Effectiveness

Such campaigns assume that boaters will act upon the information that is provided to them, but research shows that raising awareness of the problem is usually insufficient by itself to effect change in environmental behaviours (Kollmuss & Agyeman 2002). Situational constraints including economic barriers, social norms or pressures within the target group, and limited opportunity to effect change can limit voluntary uptake of measures, even when there is a will to act responsibly (Blake 1999, Reaser 2001).

Research commissioned by MPI on the effectiveness of a communication campaign targeted at recreational boaters following discovery of the invasive sea-squirt, *Styela clava,* in 2005 tends to support these findings. The campaign advocated cleaning of marine vessels to prevent transport of *S. clava* and other harmful biofouling organisms (UMR Research Ltd 2006). The study showed that only 18% of the respondents who had seen communications material relating to the *Styela clava* campaign claimed that they were acting on the information and taking different actions as a result of it. Vessel owners who were unwilling to clean their boat in response to the campaign suggested they may be encouraged to do so by:

- more information on the reasons why it was necessary,
- financial assistance,
- providing access to equipment and facilities, and
- linking cleaning in with regular maintenance or repairs (UMR Research Ltd 2006).

Similarly, recent studies of biofouling on recreational vessels in the Nelson-Marlborough region suggest little change in the overall levels of fouling, despite concerted campaigns to raise awareness about the problems caused by harmful marine organisms (Forrest 2013, P. Lawless pers. comm.).

Feasibility and cost of compliance

The costs of social marketing and awareness campaigns for unwanted marine organisms are typically borne by central or local government. Costs associated with haul-out and cleaning of recreational vessels are described in Section 7.7.7.

Expected rate of uptake

Existing studies suggest that voluntary uptake of measures promoted in the "Clean Boats" campaigns has been limited. Reasons for the lack of uptake are unclear as the greater availability of travel-lift facilities in major centres for recreational boating (e.g., Auckland, Northland, Bay of Plenty) has made haul-out and cleaning a quicker and more affordable option for owners of small (<20 m) moored vessels than it has been previously. Nevertheless, these facilities are not available in all regions. Because of the time and costs associated with haul-out and cleaning, owners of recreational vessels tend to get a number of maintenance tasks done when the vessel is out of the water (e.g., for re-fit, cleaning, engine servicing, re-painting, etc.). This may mean that they are reluctant to undertake additional cleaning outside of their normal schedule of maintenance and repair (see also Sections 7.7.6 and 7.7.7).

7.7.6 Application and maintenance of an appropriate anti-fouling coating

Recreational craft have a variety of designs, operating speeds, use patterns and voyage profiles. The effectiveness of anti-fouling coatings used by the craft depend on the coatings' suitability to the design and operations of the vessel, whether they were applied in accordance with the manufacturer's specifications and how long they have been in use (Floerl et al. 2010, Piola & Forrest 2009). Most (~70%) non-trailered recreational craft use ablative Controlled Depletion Polymer (CDP) or Self-Polishing Copolymers (SPC) anti-fouling coatings, with the remainder using hard-type conventional coatings (Floerl et al. 2010, Floerl et al. 2008). The effectiveness of ablative coatings declines over time as the biocide leaches from the paint matrix. Hull surfaces can become significantly fouled towards the end of the paints' service life, or if the coating fails prematurely. The generic recommended service life for ablative anti-fouling coatings is 12 months (MAF Biosecurity New Zealand 2011), but many recreational vessels do not renew the coatings this frequently. Because there is no certification survey requirement for recreational vessels and biofouling does not impose as great a penalty on operating costs as it does for commercial vessels, the frequency with which the vessels are removed from the sea for maintenance and anti-fouling is generally at the owners' discretion or determined by the need for repairs. Also, unlike larger merchant vessels, a significant proportion of recreational vessels have the anti-fouling coatings applied outside professional facilities, by the owner or similar "Do it yourself" (DIY) operators (MAF Biosecurity New Zealand 2011, Thompson Clarke Shipping Pty Ltd et al. 2007). Incorrect surface preparation or application of the coatings can shorten their effective service life.

In a review of anti-fouling performance standards in Australia, Thompson Clarke Shipping Pty Ltd et al. (2007) recommended that a licensing scheme be established to provide technical oversight of professional ship painting facilities and that application of coatings on domestic recreational craft be managed through a combination of regulation, codes of conduct and guidelines. They made the following recommendations.

- For ships and boats painted by commercial applicators, the applicator will need to be able to establish that they have an effective quality management system, the necessary technical competence and a track record of success.
- For ships and boats that are painted by non-professional, DIY applicators, the accepted service life of the certified anti-fouling paint should be restricted to a period of not greater than 12 months.

Some of these recommendations have been incorporated in the *Draft Anti-fouling and In-water Cleaning Guidelines* for New Zealand and Australia (MAF Biosecurity New Zealand 2011). This document provides guidance for professional and DIY applicators of anti-fouling coatings and recommends three ways of maintaining appropriate documentation on the coating application.

- Through maintenance of a Biofouling Management Plan (BMP) and Record Book.
- As an Anti-fouling System Certificate or Declaration on Anti-fouling System.
- In original receipts or invoices that state the coating type, volume purchased, vessel name and date of application.

Effectiveness

General improvements in the selection and application of anti-fouling coatings for recreational vessels will increase their performance during the recommended service life of the coating. However, the overall effectiveness of this measure in reducing spread of harmful biofouling will be determined by the proportion of vessels that renew the anti-fouling coatings within or at the recommended service life of the coatings (generally 12 months for ablative coatings).

Feasibility and cost of compliance

The *Draft Anti-fouling and In-water Cleaning Guidelines* for New Zealand and Australia include specific guidance for the choice and application of anti-fouling coatings by professionals and non-professionals (MAF Biosecurity New Zealand 2011). The guidelines have no legal status but are intended to support decisions made by environmental managers when carrying out resource planning and/or consenting/permitting functions in relation to the cleaning and maintenance of vessels and movable structures. Maintenance of vessels on land must comply with the Resource Management Act 1991 and plans prepared under it, so to give force to the measures contained in the guidelines, regional councils (including unitary authorities) and territorial authorities would need to incorporate the measures into consenting or find alternative instruments (e.g., provision of information or accreditation schemes) to encourage their implementation by professionals and non-professionals.

Expected rate of uptake

Because biofouling does not impose as great a penalty on operating costs of recreational vessels as it does for commercial vessels, improvements in the performance of anti-fouling coatings may not be a strong incentive for vessel owners to adopt the recommended measures voluntarily, particularly if this is likely to mean also renewing the anti-fouling (and the associated costs) more frequently than they currently do.

7.7.7 Removal from the water for cleaning on land

For most recreational vessels, removal of the vessel from the water for cleaning and maintenance is preferable to in-water operations because the risks from biofouling organisms and toxic contaminants can be more easily contained (MAF Biosecurity New Zealand 2011). Depending on the size of the vessel and amount of biofouling present, it can take just a few hours to haul-out and clean a recreational vessel. Cleaning of large, heavily-fouled vessels may take longer (Inglis et al. 2012). In most shore-based facilities in New Zealand, biofouling is removed by water-blasting and the waste material is disposed of in landfill (solid waste) and by discharge to storm-water (liquid waste) (Woods et al. 2007). A survey of Californian boatyard facilities showed that cleaning times for recreational vessels were influenced by the length and type of boat, the type of hull coating and season of the year (Johnson & Fernandez 2011). On average, for boats that ranged from to 8 m long to up 18 m long, hull cleaning required 1 person and 28 to 78 min.

Some vessels (e.g., racing yachts) may be removed from the water on a regular basis to clean off light fouling. These will often be vessels that have hard Surface Treated Composite (STC) coatings that do not have a biocide, but which require regular “grooming”. Some boat-maintenance companies offer special rates for haul-out and cleaning in such cases (Basil Hart, Dickson Marine Nelson, pers. comm.).

Effectiveness

Haul-out and high-pressure water-blasting is an effective method for removing biofouling. The power of the water-blast may be varied depending on the type of anti-fouling coating on the hull (e.g., silicone based paints require gentler treatment), but is usually up to 8,000 psi (Floerl et al. 2010). Water-blasting is less effective for treating biofouling in recessed areas, such as seawater inlet pipes and gratings. These niche areas may be treated using other methods, such as flushing with freshwater, detergents or chemicals (e.g., bleach) (Section 3.10.4). When vessels are hauled out for cleaning there is the risk that mobile organisms within the biofouling will escape and that some sessile organisms will be dislodged when the vessel enters the cradle (for slipways) or slings (travel-lifts) (Coutts et al. 2010).

Feasibility and cost of compliance

Removal of vessels from the water can be achieved by a range of methods, the choice of which depends on the size of the vessel and the infrastructure available. A summary of marina and shipyard facilities in New Zealand that can haul-out vessels up to 1,800 t (most recreational vessels fall into this category) is presented in Appendix 1. Where they are available, travel-lift facilities make it easy to haul-out and return vessels to the water safely and quicker.

Charges for haul-out, storage and water-blasting of vessels vary among facilities and with the size of vessel. An indicative summary of charges based on the published rates for four representative boatyards is presented in Appendix 2. For small vessels (<9.1 m length), haul-out and storage for a day can range from NZ$120 to $250, depending on the facility. For larger vessels (20-22 m length), the comparable rates are NZ$620 to $1481 per day.

Expected rate of uptake

Owners of many yachts and launches already make regular use of haul-out facilities for cleaning, anti-fouling and maintenance. Encouraging more frequent use of these facilities by boaters will require greater national access to low-cost operations.

7.7.8 In-water cleaning of vessels

The ablative anti-fouling coatings that are used on most recreational vessels in New Zealand are designed to slough off layers of paint matrix and biocides as the vessel moves. A side-effect of this sloughing effect is that the coating surface is prone to damage by excessive abrasion (Morrisey et al. 2013). In-water cleaning of biofouling with tools such as brushes and scrapers can damage these coatings, removing layers of paint and releasing a pulse of biocide that can contaminate the marine environment. For these reasons, and because potentially harmful marine organisms (or their offspring) may be released during in-water cleaning, it is recommended only when it does not harm the anti-fouling coating and presents an acceptable biosecurity or contaminant risk (MAF Biosecurity New Zealand 2011, Morrisey et al. 2013).

A recent analysis of the biosecurity and contaminant risks associated with in-water cleaning made the following recommendations for recreational vessels (Morrisey et al. 2013).

- In-water cleaning is considered **unacceptable** for all vessel types with LoF >3, even when capture technologies are used to retain waste. In these instances vessels should be hauled out for cleaning.
- Vessels with biocide-free anti-fouling systems may in-water clean if waste can be captured and there is high confidence that the fouling is of local origin.
- In-water cleaning (with capture) by hand removal of spot fouling (LoF ≤3) may be acceptable and is preferred to not cleaning (if a vessel has travelled to another region) for visits of >48 h duration.

For most recreational vessels, removal of the vessel from the water for cleaning and maintenance is preferable to in-water operations (MAF Biosecurity New Zealand 2011). Non-toxic fouling release coatings or hard STC coatings may require regular grooming to keep them free of biofouling. This is usually done using soft cleaning tools, such as cloths, squeegees and wiping tools.

Several types of biofouling treatment are available that kill biofouling organisms but do not actively remove them from a surface. These include the use of heat (in the form of steam or heated water) or enveloping technologies (wrapping of a vessel or movable structure in plastic sheets or canvas sleeves to suffocate biofouling). These are generally developing technologies and their effectiveness and effects on anti-fouling coatings have not been evaluated fully (Inglis et al. 2012, MAF Biosecurity New Zealand 2011).

Effectiveness

Detailed assessments of the advantages and risks of in-water cleaning of biofouling are presented in Floerl et al. (2010), MAF Biosecurity New Zealand (2011), Inglis et al. (2012) and Morrisey et al. (2013).

In-water removal of biofouling by hand or using manual tools is only likely to be effective for vessels with sparse biofouling that is concentrated in small areas. Studies have shown that it is difficult to retain all of the biological waste and organisms during cleaning without use of sophisticated containment systems (Woods et al. 2007).

Feasibility and cost of compliance

Although the cleaning of small areas of biofouling and small vessels can be implemented relatively quickly and cheaply using this method, there are currently no approved facilities for in-water decontamination of vessel biofouling. Approved facilities would require resource consent under the Resource Management Act 1991.

Expected rate of uptake

For most recreational vessels, removal of the vessel from the water for cleaning and maintenance is preferred to in-water operations (MAF Biosecurity New Zealand 2011).

7.7.9 Alternative methods to prevent or reduce biofouling

Boat lifts and liners

Other methods to reduce the build-up of biofouling include the use of boat lifts, which can elevate the boat out of the water (Johnson et al. 2012) and slip (berth) liners (a form of encapsulation) whereby the boat is driven into a plastic liner at its berth and the liner closed behind it, creating a closed pool of water, to which freshwater or chlorine can be added to kill or inhibit fouling (Johnson et al. 2012).

Effectiveness

We could find no published information on the effectiveness of boat lifts or slip liners in reducing biofouling, but expect they will be very effective. Boat lifts will reduce the amount of time that the vessel is in the water and available for colonisation by biofouling organisms. Any biofouling organisms that do colonise the hull surfaces may die as a result of desiccation, if the vessel is out of the water for long enough. Similarly, slip liners should reduce colonisation pressure on the hull and can be treated to kill or inhibit fouling.

Feasibility and cost of compliance

A variety of models of boat lift is available in New Zealand to fit different boats and dock applications. Advertised facilities are capable of lifting vessels up to 54 t. In New Zealand bespoke boat lifts are customised to the vessel and the situation in which it is moored. (Johnson & Fernandez 2011) reported mean minimum cost for boat lifts in California at the equivalent of NZ$4,200 (SD $5,900) and mean maximum cost of NZ$34,000 (SD $34,000).

Slip liners are available for vessels up to 18 m in length and range in price from ~NZ$2,500 for a 9 m vessel to NZ$7,500 for an 18 m vessel (Johnson & Gonzalez 2008).

Expected rate of uptake

Despite their availability on the market, there has not yet been large uptake of boat lifts and slip liners in New Zealand. This may be because the capital costs of purchase relative to the costs of regular haul-out and anti-fouling provide a barrier to their use.

7.7.10 Ultra-sonic anti-fouling

Several companies have advertised commercial ultra-sonic devices to inhibit biofouling on recreational vessels[62]. Ultra-sound is sound pressure waves that have a frequency greater than the upper limit of the human hearing (normally >20 kHz). Different ultra-sonic frequencies inhibit biofouling in different ways: by elevating temperature, by ultra-sonic wave-induced force, by ultra-sonic cavitation or through a combination of these mechanisms (Guo et al. 2011). In laboratory settings, cavitation has been shown to inhibit bacterial growth, barnacle settlement, and to remove algae and biofilms. Cavitation occurs at relatively high acoustic pressures (>20 kPa) and is much stronger at lower ultra-sound frequencies (19-23 kHz) (Guo et al. 2011). Barnacle larvae are killed by relatively short (5 min) exposure to these quite high acoustic pressures (Guo et al. 2011, Seth et al. 2010). However, cavitation does not occur at low acoustic pressure (<5 kPa), and Guo et al. (2012) showed that barnacle larvae were not killed by sound frequencies of 23 kHz or greater. Settlement was, however, reduced after 24 h exposure, presumably as a result of larvae not attaching to the vibrating surface. The extent of biofouling prevention, therefore, depends on the frequency range used by the ultra-sonic device and its power output, which will also be influenced by how it is installed, programmed and maintained on a vessel.

Recent research has raised the possibility of using cavitating water jets generated by ultra-sound as an environmentally safe alternative to mechanical grooming of hull surfaces (Guo et al. 2013) or in automated cleaning stations (Mazue et al. 2011). Preliminary results show promise for removing early stage biofouling while minimising damage to ablative and hard anti-fouling coatings.

Effectiveness

These technologies are still in development and require further testing to determine their effectiveness in situ.

Feasibility and cost of compliance

Ultra-sonic anti-fouling devices are available in New Zealand for a variety of small vessels, with prices starting at around NZ$1,000 for a low power unit suitable for a 14 m vessel. Larger, more powerful units are marketed for vessels up to 50 m length and for treating marina berths[63].

Although relatively high intensity ultra-sound shows promise as an anti-fouling strategy, Guo et al. (2012) have cautioned against its use until "*a full and thorough assessment of the effect of ultra-sound on the marine environment*" has been undertaken. Acoustic energy attenuates less in water than in air so that sound waves can travel over long distances with little reduction in energy (Slabbekoorn et al. 2010). Some fish and marine mammals are sensitive to high frequency and high pressure sound and, to our knowledge, its impact on other, non-target organisms at the frequencies and pressures used by anti-fouling devices has not been determined.

Expected rate of uptake

At present, ultra-sonic devices appear to have had relatively little penetration into the New Zealand recreational boating market, despite systems being available for several years. Although various testimonials by users attest to the utility of ultra-sonic anti-fouling devices for small vessels, we are not aware of any independent scientific validation of their effectiveness in a field setting and questions remain about their utility. If they can be demonstrated to be effective against biofouling and low cost to maintain, then we would

[62] http://www.ultrasonic-anti-fouling.com/
http://ultrasonic-anti-fouling.com.au/home.html
http://www.aquasonicmanagement.com/
http://www.shipsonic.com/index.html
[63] http://www.aquasonicmanagement.com/marina-berths/

expect reasonable uptake by vessel owners in preference to more frequent use of toxic anti-fouling coatings.

7.8 Available practices to reduce risk – bilges and other water containing spaces on vessels

A detailed discussion of methods to treat bilge spaces and stored water on vessels is presented in Section 3.8 of this report.

The recommended practices for treatment of bilges and water in contained spaces on all vessels are:

- discharge and emptying of water before departing from a location,
- retention and storage of water for discharge to shore-based treatment,
- regular flushing with freshwater or an approved treatment as a preventative measure to keep the spaces clean, or
- treatment of water spaces with an approved treatment (Cawthron Institute 2013, Commonwealth of Australia 2009b, International Maritime Organization 2012, MAF Biosecurity New Zealand 2007a).

The first three of these options are generally preferred over chemical treatment of water spaces.

Effectiveness

Most small recreational vessels will not have dedicated systems for separating oil from waste-water, but will have bilge pumps that are operated manually or automatically, on-demand. In-line filters can be fitted to these systems to remove contaminants from the flow. These are likely to provide some protection against discharge of harmful marine organisms by removing larger organisms and/or fragments from the discharge stream, but it is unclear how effective they would be at retaining planktonic propagules.

There is a need for more guidance on the chemical treatments that are effective in reducing the biosecurity risk of seawater held on vessels and whether they are approved for discharge in New Zealand waters (See Section 3.8). However, the Ministry for the Environment and Ministry of Tourism (unknown), the New Zealand Marina Operators Association (2008) and Maritime New Zealand do not recommend use of bilge cleaning products as they can be toxic to marine life and disperse the oil contained in the bilge rather than remove it. Instead, the recommended practice is to retain the seawater and pump it out to shore-based treatment facilities (where available), rather than discharging at sea and, where necessary, to use enzyme-based bilge cleaners in preference to detergents.

Feasibility and costs of compliance

The most feasible options for recreational boaters are likely to be discharge and emptying of water prior to relocating and, for trailered vessels, retention of small quantities of water for discharge on land during washdown.

The costs of compliance are likely to relate more to operational procedures than to financial outlays. If feasible practices can be identified, the costs of implementation could be relatively modest. There will be associated costs to government or regional authorities in raising awareness and in verification and auditing of compliance with the recommended measures.

Expected rate of uptake

Research is needed to quantify the actual risk from bilge water to determine what type of measures might be appropriate (See also Section 3.8.4).

To achieve a high uptake, measures to manage bilge water would need to be simple and practical. The actual risks associated with transport of bilge and methods for managing them need to be communicated widely.

7.9 Available practices to reduce risk –contaminants on vessels

7.9.1 Manual removal and washdown

Effectiveness

Visual inspection of trailered vessels and equipment, followed by washing with freshwater can significantly remove the likelihood that harmful organisms will be transported (Rothlisberger et al. 2010). In a study of small boats at ramps on freshwater lakes in the USA, (Rothlisberger et al. 2010) found that visual inspection and hand removal reduced the amount of macrophytes from the exterior of boats and trailers by 88% (± 5% SE), with high-pressure (~1,800 psi) washing equally as effective (83% ± 4%) and low-pressure (mains water pressure) washing less so (62% ± 3%). High-pressure washing was most effective at removing small-bodied animals (91% ± 2% removal rate) with low-pressure washing and hand removal less effective (74% ± 6% and 65% ± 4% removal rates, respectively).

Feasibility and cost of compliance

Wash down facilities are already provided at many public boat ramps and are used regularly by owners of trailered vessels. Limits in the number of wash down facilities relative to the numbers of boats using ramps or other access points can mean that washing does not always occur at the point where the boat is removed from the water.

Expected rate of uptake

The study by Rothlisberger et al. (2010) suggested that many boaters in the lakes of Wisconsin and Michigan had not yet adopted consistent and effective habits for cleaning their boat. Sixty-seven percent of boaters did not always clean their boat when moving between water bodies, nor removed attached weeds when they saw them. This was despite a relatively vigorous education campaign in that region of the USA. Therefore, additional measures may be necessary to achieve better uptake. Rothlisberger et al. (2010) also noted that the highest risk was from boaters who regularly moved between multiple water bodies. This proportion is likely to be much smaller for coastal recreational boaters. Because of the corrosive effects of salt water on engines and other boat components many boat owners already flush outboard motors with freshwater and hose down their boat once it is removed from the seas.

7.9.2 Exclusion or quarantine zones

In some cases, risk may be mitigated by excluding vessels and equipment from areas containing nuisance macrophytes and other harmful species that are likely to contaminate boats. In Australia, for example, declaration of a quarantine area or pest control area for pest management can mean that vessels are prevented from entering or leaving areas known to be infested by a harmful organism. Measures may also include restrictions on specific activities to prevent the vessel from becoming contaminated. For example, no-anchoring zones were declared in New South Wales, Australia as part of the strategy to manage the spread of the seaweed, *Caulerpa taxifolia* in estuaries (West et al. 2007). West et al. (2007) also proposed a 3-day quarantine period for boats travelling between water bodies.

Effectiveness

Quarantine and exclusion zones are likely to be effective at reducing further spread of the organism when vessels (or other recreational activities) are one of the principal vectors for spread. They are likely to be less effective at reducing spread of species capable of dispersing long distances as adults or planktonic larvae. Exclusion zones will also only be effective if there is good definition of the spatial distribution of the harmful organism.

Feasibility and cost of compliance

The spatial extent and duration of closure of an area will be important influences on their feasibility. Short-term closures of small areas during a control or eradication programme may be more easily implemented and enforced than long-term or large-scale exclusions of use. For owners of recreational vessels, the costs are likely to be loss of amenity (e.g., inability to access fishing grounds or favoured areas for other recreational activities). For government, costs will be incurred in surveillance (to define the extent of the zone) and enforcement.

Expected rate of uptake

Acceptance of exclusion zones or restrictions on movement is likely only when there are clearly demonstrated (and severe) risks from spread of the harmful organisms and the area(s) in which activity is restricted are small in comparison to the total area available for desired recreation.

7.9.3 Chemical treatments

Dunmore et al. (2011) reviewed different chemicals and treatment methods that have been applied to remove harmful organisms from marine equipment once removed from the water and drafted guidelines for their use. The best treatment for a particular type of equipment depends upon: (1) the time available before moving to another water body (e.g., treatment by desiccation through exposure to air can take up to 1 month to be effective), (2) access to appropriate chemicals, (3) the size of the item/s and its suitability to the treatment methods (e.g., a kayak may be too big to soak so spraying or air exposure is likely to be a better approach), and the (4) sensitivity of equipment to the cleaning method. Recommendations from Dunmore et al. (2011) are summarised in Table 4-3.

Expected rate of uptake

Discussion on the effectiveness, feasibility and costs of compliance for treating marine equipment with chemicals is provided in Sections 4.9, 5.12, and 6.9 of this document. Voluntary uptake of chemical treatments within the recreational sector is expected to be low unless incentives are provided (e.g., provision of dedicated wash stations with suitable treatments provided) and may be unnecessary if there is widespread use of freshwater washing and air-drying of equipment.

7.10 Available practices to reduce risk – pontoons and moorings

Management of populations of harmful organisms in areas where there are large numbers of boats or other potential vectors (“source control”) can slow the rate of spread if the population is culled to a level that reduces infestation of the vectors. Drury and Rothlisberger (2008) showed that this strategy is most effective when the organism is not widespread (i.e., when there are few infested locations relative to the number of locations the organism could spread to).

7.10.1 Cleaning, air-drying and encapsulation

Piola and Forrest (2009) identified three potential tools for managing biofouling assemblages in marinas.

- Periodic removal and cleaning of pontoons, moorings and other infrastructure.
- Cleaning and / or removal from the water for sufficient time to kill fouling organisms of any structure that is to be moved to another location (such as reuse of marina pontoons).
- Encapsulation (or ‘wrapping’) (see also Sections 3.10.3, 4.9, and 6.3).

Effectiveness

Cleaning and air-drying for a sufficient period of time to kill fouling organisms are effective treatment methods for structures and equipment that can be removed from the water (e.g.. mooring blocks, ropes and buoys; see also Sections 4.3.2, 6.1.2, and 6.6). Air-drying, without water-blasting or manual cleaning of the structures is less effective by itself, unless the structure can be left out of the water for longer than 21 days (see the discussion on air drying in Section 6.6.6).

Encapsulation is a more suitable option for fixed (e.g., wharf piles) and heavy structures that are difficult to remove from the water (e.g., pontoons). This method was originally developed for eliminating the sea squirt *Didemnum vexillum* from wharf piles in Shakespeare Bay near Picton (Coutts & Forrest 2007), but has been adapted for application to marina pontoons and vessels (Coutts & Forrest 2005). Encapsulation methods were used and further developed as part of the Top-of-the-South *Didemnum* management programme. Discussions of the effectiveness of encapsulation can be found in Sections 3.10.3, 4.9, and 6.3.

Feasibility and cost of compliance

In many jurisdictions, established moorings require regular inspection and cleaning by an approved contractor every 2 to 3 years to ensure their structural integrity. This is true in Auckland[64], Northland (Northland Regional Council 2012), Waikato (Waikato Regional Council 2012), the Bay of Plenty(Bay of Plenty Regional Council 2011), Marlborough (Piola & Forrest 2009a), Canterbury (Environment Canterbury 2006) and the Nelson district (Dave Duncan, Port Nelson Harbourmaster, pers. comm.).

Marlborough Regional Council currently requires all swing moorings in the Marlborough Sounds to be inspected, repaired and cleaned every two years at a cost to mooring holders of ~NZ$200-300 dollars, excluding any materials required (Piola & Forrest 2009). Other regional authorities have similar requirements for inspection

The ease with which floating pontoons can be removed from the water depends upon their size and mode of construction. Walkways in modern marinas will typically be constructed using precast concrete pontoons that are secured within timber, galvanised steel or aluminium framing. These may be as modular units that are secured together or as large, one piece sections. Removal from the water will usually require use of a barge and heavy lifting equipment. Other, lighter plastic pontoon systems are used in some situations (i.e., where greater flexibility is required).

Coutts and Forrest (2005) estimate the costs of wrapping floating pontoons at ~$150 per 3 m x 3 m section, with around ⅔ of that being labour costs. Adding acetic acid or sodium hypochlorite solution to accelerate mortality would add an estimate $10 or $35, respectively, per 3 m x 3 m section. The cost of wrapping 178 wharf piles during the *Didemnum* management programme was estimated at NZ$35,000 (Coutts & Forrest 2007).

Expected rate of uptake

Regular inspection and maintenance of swing moorings is already a requirement of consents in many regions. Biosecurity considerations (e.g., requirements to clean the moorings, dispose of waste on land and have a stand-down period on land before deployment to a new area) could be included within the consenting conditions.

Treatment of pilings and pontoons is likely to be an expensive undertaking for marina operators and voluntary uptake is likely to be low.

[64] http://www.aucklandcouncil.govt.nz/EN/parksfacilities/beacheslakeswaterways/moorings/Pages/home.aspx

7.10.2 Novel anti-fouling surfaces

Research is currently in progress into the development and use of novel materials and surfaces that may inhibit the establishment of fouling assemblages (Piola & Forrest 2009). Such materials could, in the future, be used to treat static biofouling surfaces, such as pontoons and moorings, for which it is not appropriate to use coatings that rely on movement through the water to release biocides. For example, the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) is currently developing a range of alternative fouling-resistant materials (Poole 2011). These include using: cold spray technology to embed copper particles into thermoplastic polymers (e.g., polythene, Vucko et al. 2012); a nano-fibre material that prevents settlement and growth of fouling organisms, including bacteria; photoactive materials that release reactive forms of oxygen to kill or repel settling organisms; and micro-structured surfaces with topographies that trap air at the water/solid interface and prevent organisms from attaching.

Effectiveness

These materials are still in development and are not available commercially.

7.11 Available practices to reduce risk – recreational fishing equipment, including live bait and catch

7.11.1 Inspection, manual removal, washing and drying of equipment

A summary of recommended approaches for washing, rinsing or drying marine equipment to reduce the risk of transporting harmful marine organisms is provided in Table 4-3.

Effectiveness

Risk may be reduced when gear is dried or rinsed in freshwater after use but organisms could remain viable if transported with damp fishing gear, particularly nets. For example, Sant et al. (1996) found that *Caulerpa taxifolia* survived periods of emersion of up to 10 days when kept in darkness, at 18°C temperature, and at high air humidity (85—90%). This suggests that, when kept in conditions such as those occurring in an anchor locker or damp fishing nets, *C. taxifolia* is able to survive long enough to allow transport to another coastal region.

Education, particularly regarding washing and drying of gear (e.g., Table 4-3), may go some way to improving practices and reducing biosecurity risks. Information could be provided at points of sale of bait and other angling equipment, boat ramps, angling competitions and angling clubs, particularly in locations where harmful organisms are known to be present.

Feasibility

Anglers and other recreational fishers are a very diffuse and widespread group, making any form of regulation difficult to enforce.

Expected rate of uptake

As discussed in Section 7.7.5, without appropriate knowledge and incentives for positive behaviours, there may be limited voluntary uptake of these practices. Some recreational fishermen will already wash-down their gear with freshwater when washing down their vessel, but they are unlikely to use detergents or other chemicals. Provision of washing stations at boat ramps, possibly including disinfectants in locations where harmful organisms are present (similar to disinfecting stations for didymo[65]) could reduce barriers to regular washing of equipment.

---

[65] The invasive, non-indigenous freshwater alga, *Didymosphenia geminate*.

7.11.2 Exclusion or quarantine zones

Restrictions on fishing in high-risk areas where harmful organisms are known to be present may also be an option, particularly where it can be demonstrated that anchoring or fishing activity has a high risk of transporting the organism (as was the situation in New South Wales, Australia, with the aquarium weed, *Caulerpa taxifolia*).

A discussion on the effectiveness, feasibility, cost of compliance and likely uptake of exclusion zones is provided in Section 7.9.2.

7.12 Available practices to reduce risk – diving equipment

7.12.1 Inspection, manual removal, washing and drying of equipment

Effectiveness

The risk of transporting potentially harmful organisms entangled with dive gear will be reduced by the common practice of washing scuba and snorkelling gear in freshwater and drying. There will be some residual risk, however, if gear is transported among locations without cleaning and drying, or if water or other material is retained inside buoyancy compensators, catch bags, or pockets of diving suits. Protocols for washing diving and other marine equipment are discussed in Sections 4.9 and 6.9.

Feasibility and costs of compliance

Education, particularly regarding washing and drying of gear, may go some way to reducing risk. Information could be targeted at points of sale of diving equipment, air-filling stations, boat ramps and diving clubs, particularly in locations where harmful organisms are known to be present. The expected costs to divers is relatively low, since it is already common practice for divers to wash their gear in freshwater after they have finished diving for the day. Use of detergents or disinfectants during wash down is not currently widespread.

Expected rate of uptake

As discussed in Section 7.7.5, without appropriate incentives for positive behaviours (or disincentives for risky behaviours), there may be limited uptake of these practices. Provision of washing stations at boat ramps, possibly including disinfectants in locations where harmful organisms are present (similar to disinfecting stations for didymo) could reduce barriers to regular washing of equipment.

7.12.2 Exclusion or quarantine zones

In some freshwater locations, such as Te Waikoropupū Springs in Golden Bay, snorkelling and diving has been banned in response to the risk of infection by didymo. A similar approach could be used in high-value marine sites.

A discussion on the effectiveness, feasibility, cost of compliance and likely uptake of exclusion zones is provided in Section 7.9.2.

7.13 Available practices to reduce risk – marine aquaria

7.13.1 Education and awareness

There was a tendency among traders of ornamental species and aquarists interviewed in Australia to assume that any specimens released would not survive in the wild (Morrisey et al. 2007). A first step in mitigating deliberate or accidental release may be to target educational material to traders clearly explaining how harmful marine aquarium species may enter natural waterways, what factors make it possible to survive, and what effects they may have if they become established.

Education of aquarists and traders could be accompanied by prohibition of the sale, holding or translocation of live specimens of any ornamental species that are not included on the list of those approved for import to New Zealand.

Effectiveness

There is limited information about the marine aquarium trade and the behaviour of hobbyists in New Zealand in relation to release and disposal of traded species. It is, therefore, difficult to assess the level of risk and the effectiveness of a targeted education campaign. A search of the New Zealand Marine Aquarium Society forum[66] shows some awareness among hobbyists that *Caulerpa taxifolia* is an unwanted species that is regulated within New Zealand, but also a desire from some to source species of *Caulerpa*, including New Zealand species.

Feasibility and costs of compliance

Traders surveyed in Australia showed a willingness to provide information to customers in the form of direct advice or brochures and other published material on appropriate handling and disposal of unwanted stock, and many already do so, although none of those surveyed displayed material on harmful marine organisms, possibly reflecting lack of access to, or awareness of, suitable material (Morrisey et al. 2007). More than 90% of retailers said that they would consider displaying material on handling and disposal of unwanted stock and on marine biosecurity.

As an example, the Habitattitude™ campaign in the USA[67]. is a national initiative developed by the intergovernmental Aquatic Nuisance Species Task Force[68] and its partner organisations. The U.S. Fish and Wildlife Service is the lead federal agency for Habitattitude™ and the programme has the support and involvement of the pet and aquarium trade (through the Pet Industry Joint Advisory Council) and the nursery and landscape industry. In addition to the involvement of these industries, key players are the National Sea Grant College Program and state fish and wildlife agencies. The programme *"…is about consumer awareness and responsible behaviors. By drawing attention to the potential environmental ramifications of the aquarium and water garden hobbies while promoting responsible consumer behaviors, HabitattitudeTM avoids the definition debate surrounding "invasive species." Ultimately, the campaign seeks to eliminate the transfer and survival of any species outside of your enclosed, artificial system, which has the potential to cause the loss or decline of native plants and animals*".

There are costs for government associated with developing and implementing an awareness campaign for this sector.

7.14 Available practices to reduce risk – beach management

7.14.1 Consenting of beach management activities

Applications for resource consent to move beach materials for the purposes of renourishment could be required to include assessment of biosecurity risks of translocating material, including harmful marine organisms present at the source location (See also Section 3.11 regarding operational management tools for dredged material and factors to be considered in risk assessments).

Monitoring conditions in consents could be required to include reporting of any non-indigenous species found and any change in their abundance and distribution over time. These assessments should be done prior to each translocation.

[66] http://www.nzmas.co.nz/forum/index.php
[67] http://www.habitattitude.net/, accessed 11 April 2013.
[68] http://www.anstaskforce.gov/default.php, accessed 11 April 2013.

Treatment of the translocated material may be possible if there is a significant biosecurity risk, but the volume of material involved is likely to preclude this and any use of toxicants must be balanced against the need to minimise ecological impacts at the destination.

Effectiveness

Incorporating assessment of the potential for transfer of harmful marine organisms into the consenting requirements for beach renourishment programmes would ensure that the risks are considered and mitigation strategies are proposed.

Feasibility and cost of compliance

This measure would require that proponents of beach nourishment programmes undertake baseline assessments (through desktop study or field survey) of the source locations to determine if harmful organisms are likely to be present. There will also be costs associated with any mitigation of risk that may be required (e.g., using an alternate source of material or treating materials sourced from infested locations).

Expected rate of uptake

Including assessment of biosecurity risks in consent applications could be implemented relatively easily by consenting authorities, but will involve additional cost to applicants.

7.15 Sport and recreation - summary of recommendations

A large variety of recreational activities have the potential to spread harmful marine organisms. High participation rates in marine recreation coupled with the lack of national registration or licensing of these activities makes it difficult to achieve high uptake of management measures within this sector. There are, nevertheless, existing options for managing most risks within the sector if policy mechanisms can be found to encourage uptake.

Simple measures are available to reduce risks from trailered vessels and immersible equipment such as scallop dredges, diving equipment, anchors, etc. These include inspection, cleaning and drying of the vessel, trailer and equipment after each journey or trip, removing attached biofouling or entangled organisms and rinsing and drying hull compartments. Uptake of these practices could be encouraged through greater availability of wash-down facilities at boat ramps and access points and targeted education and awareness campaigns.

As with other vessel types, the level of risk posed by bilge water from recreational vessels is unclear and would benefit from further research. Some mitigation may be achieved by encouraging use of in-line filters and manual discharge of bilge prior to moving outside the region. For trailered vessels, residual bilge is likely to be emptied from the vessel when it is hauled from the water, particularly during wash-down.

For non-trailered vessels the greatest risks are likely to be from the transport of biofouling. The most effective options for reducing this risk are through cleaning in approved shore-based facilities (particularly prior to movement from the region) and better use of antifouling coatings. Four options are recommended to encourage better uptake of biofouling management in this sector.

Provide education and/or incentives for use and maintenance of anti-fouling coatings that are suited to the vessel's activity.

- Require vessel operators to follow an approved BMP (as recommended by the IMO).

- Require vessel operators to notify authorities in advance of intentions to visit specified high value areas, some of which could require approval and possibly an inspection.
- Impose movement controls on vessels that exceed a threshold LoF unless they can demonstrate compliance with an approved BMP.

Existing structures or associated materials that have been in the marine environment should not be moved to another region, or substantial distances within a region, without first being sterilised (preferably by removal from the water for cleaning). We recommend that local authorities require, as a condition of resource consents or permits (e.g., for moorings), that any new structures in the coastal environment be made using only new or appropriately sterilised materials.

8 Research and education pathway

8.1 Nature of the pathway

The research and education sectors include Crown Research Institutes and other science providers, marine environmental consultancies, universities and polytechnics (including marine laboratories), and commercial aquaria (all of which have educational objectives and, in some cases, conduct research too).

8.1.1 Crown Research Institutes and other science providers

The National Institute of Water and Atmospheric Research (NIWA)

NIWA is the largest Crown Research Institute working in the marine environment and conducts marine research through its centres in Bream Bay, Auckland, Hamilton, Wellington, Nelson, Christchurch and Dunedin. The main Wellington campus (in Evans Bay) and those at Hamilton, Nelson and Christchurch contain recirculating aquarium systems that are operated as and when required and the Wellington campus also has a flow-through system.

Bream Bay and the recently-decommissioned (but still operating in June 2013) Mahanga Bay facility in Wellington are aquaculture research facilities with flow-through and recirculating seawater aquaria systems for finfish and shellfish. Facilities at Bream Bay include a hatchery, nursery and wet and dry laboratories. There are also specialised finfish and shellfish research and production areas, a heat- and light-controlled brood-stock room for out-of-season spawning, and a marine pathology unit with quarantine facilities for housing animals from the wild.

All of the campuses operate trailered boats (up to 9.5 m long). NIWA Vessels Company, based on the Wellington campus, operates two vessels, ca 14 m length, that are kept berthed in Evans Bay Marina, and two ocean-going research vessels, Tangaroa (70 m) and Kaharoa (28 m). Tangaroa and Kaharoa are usually berthed on Miramar Wharf in Evans Bay when not at sea. They operate throughout New Zealand’s EEZ and internationally.

The campuses listed above also possess dive gear and sampling gear and instruments, such as grabs, corers, dredges, sleds, fishing nets, trawls, oceanographic instruments (for example, current meters), buoys and anchoring systems. Some of these instruments may be deployed continuously for several months. Of specific relevance to marine biosecurity are the sets of crab traps, associated ropes, anchors and buoys, and benthic sleds used for the Marine High Risk Site Surveillance Programme of targeted surveys for non-indigenous marine species, conducted by NIWA on behalf of MPI at six-monthly intervals at 11 ports and marinas of first-entry around New Zealand. When this equipment is not in use, it is generally stored at Bream Bay (the set used for surveys of North Island ports) and Christchurch (the set for South Island ports). NIWA has also carried out targeted surveillance for regional councils, baseline biological surveys of ports for MPI, and delimitation surveys following incursions of several NIS, including the ascidian *Styela clava* and the fanworm *Sabella spallanzanii*.

Field experiments with non-indigenous species are carried out at all of the above campuses, with the exception (to date) of Dunedin. These have included translocations of non-indigenous species from incursion locations to NIWA campuses in other parts of the country (housed in recirculating aquaria) and manipulative field experiments on non-indigenous species at the incursion location (for examples, *Charybdis japonica* in the Waitemata Harbour and *Sabella spallanzanii* in Lyttelton Harbour).

Plant and Food Research

Research at Plant and Food’s Seafood Research Unit in Nelson includes laboratory studies of fish physiology and behaviour, and harvesting techniques (such as trawling) to maximise product quality and species selectivity. Some of this work is done in collaboration with commercial fishing companies and the Seafood Research Unit also operates the following facilities:

- large-scale fish breeding tanks and live-handling tanks (1,000 – 10,000 L), including brood-stock tanks for snapper (*Pagrus auratus*) and growing tanks for aquaculture research,
- filtered seawater intake supply and discharge system, and
- laminar flow tank for research into seafood harvesting technologies such as trials of designs of fishing gear.

Cawthron Institute

The Cawthron Institute operates its main campus in central Nelson and the Cawthron Aquaculture Park (CAP) at Glenduan 10 km north of Nelson.

Space at CAP is let to several tenant organisations.

- The Cawthron Institute's aquaculture research group.
- SPATnz, a venture funded by MPI and the mussel industry (led by Sanfords) to develop selective breeding of Greenshell™ mussels.
- Pacific Marine Farms (a division of Aotearoa Fisheries Ltd), operating a Pacific oyster nursery and spat-growing operations. The Cawthron Institute will continue to spawn and produce Pacific oyster larvae at the site.
- Kono seafood sector (Whakatu Incorportated) has research projects in oysters, mussels, sea cucumbers and seaweed.
- Nelson Marlborough Institute of Technology runs a teaching facility.

Shellfish hatcheries and on-growing facilities operate with flow-through seawater.

The main campus operates two trailered vessels (7 and 4.2 m) for its research activities in the field, the larger of which works in Tasman and Golden Bays, and the Marlborough Sounds. There is a marine wet laboratory on the campus, with recirculating seawater supply, parts of which can be isolated from each other. Organisms of biosecurity risk (already present in New Zealand) are only rarely held in the facility. The campus also possesses dive gear and sampling gear and instruments, such as grabs, corers, dredges, sleds, fishing nets, trawls, oceanographic instruments (for example, current meters), buoys and anchoring systems. Some of these instruments may be deployed continuously for several months.

Field experiments and biological surveys are carried out in the coastal environment. These include studies of non-indigenous species, including deployment of fouling panels (usually redeployed at the same location but occasionally translocated). Most work is done in the top of the South Island, but some is done as far away as Stewart Island or offshore.

8.1.2 Marine environmental consultants

Larger consulting companies, such as Golder Associates Ltd, conduct field work throughout New Zealand using a range of sampling and experimental equipment and including baseline biological surveys and delimitation studies for target harmful marine organisms under contract to MPI. They also carry out laboratory studies for management of harmful organisms, which may require translocation of non-indigenous organisms.

Numerous small environmental consultants conduct surveys of marine habitats and species using (usually trailered) boats and a wide range of sampling gear. Smaller companies tend to work locally but this is not always the case, and they may also work throughout New Zealand and overseas.

8.1.3 Universities and polytechnics

Several of New Zealand's universities and polytechnics run marine biology or aquaculture courses and several operate marine laboratories.

- The University of Auckland Leigh Marine Laboratory.
- Massey University Auckland Campus.
- Auckland University of Technology.
- Waikato University main campus (Hamilton) and Marine Laboratory (Tauranga).
- Bay of Plenty Polytechnic (Tauranga).
- Victoria University of Wellington main campus and Coastal Ecology Laboratory (Island Bay).
- Nelson Marlborough Institute of Technology main campus (Nelson) and The Glen aquaculture facility north of Nelson (operated by the Cawthron Institute).
- University of Canterbury main campus and Edward Percival Marine Laboratory (Kaikoura).
- Otago University main campus and the Portobello Marine Laboratory.

The University of Auckland Leigh Marine Laboratory

The laboratory operates a 15 m vessel that is surveyed to operate between East Cape and the Three Kings Islands, but generally operates within the area bounded by the Poor Knights, Mokohinau and Great Barrier Islands. It is kept on a mooring when not in use. A range of diving gear, oceanographic instruments and sampling equipment is used. Live specimens of non-indigenous species are occasionally kept at the laboratory for research purposes, including the crab *Charybdis japonica* (Richard Taylor, Leigh Marine Laboratory, pers. comm.).

Auckland University of Technology

The university operates two trailered vessels for marine research and has aquaculture simulator facilities and marine aquaria.

Bay of Plenty Polytechnic

The polytechnic's School of Applied Science has a 7 m trailered vessel and an 11.5 m vessel that is kept in the water. The school also has a range of diving and sampling gear.

University of Waikato

The university has two trailered vessels (up to 6 m) based at its main campus and four trailered vessels (up to 9 m) based at its Marine Laboratory in Tauranga. A range of diving gear, oceanographic instruments and sampling equipment is used. The Marine Laboratory currently has a small, recirculating aquarium, which is expected to expand in the future (Chris Battershill, University of Waikato, pers. comm.). No work on non-indigenous species is being done at the main campus at present, but work on *Undaria pinnatifida* is planned at the Marine Laboratory (Conrad Pilditch and Chris Battershill, University of Waikato, pers. comm.).

Victoria University of Wellington Coastal Ecology Laboratory

The laboratory has four trailered vessels (up to 8.5 m). It has two wet laboratories with access to raw and filtered, flow-through seawater. A range of diving gear, oceanographic instruments and sampling equipment is used. Members of the laboratory conduct research in the local marine environment and also in tropical locations across the Pacific, where their instruments and dive gear are used (James Bell, Victoria University, pers. comm.).

Nelson Marlborough Institute of Technology

The institute has a freshwater aquaculture facility at its campus in Nelson, equipped with aquaria. Dive gear is owned by individual members of staff or students. Fishing gear (including electrofishing) is used only in freshwater. The marine component of the Aquaculture Programme shares a vessel with the Maritime Programme and shares seawater aquaculture facilities with the Cawthron Institutes Glen Aquaculture Facility (Charmaine Gallagher, NMIT, pers. comm.).

University of Canterbury

The main campus has three vessels, one of which is suitable for offshore work. A range of diving gear, oceanographic instruments and sampling equipment is used.

The University's Edward Percival Field Station in Kaikoura includes a large general research laboratory, a library, a smaller workroom and tank rooms as well as a large covered general working area. The laboratory has a high quality seawater system suitable for aquaculture research. Three temperature controlled rooms (10, 15 and 20°C) are available.

University of Otago Portobello Marine Laboratory

The laboratory has two vessels kept on moorings (11 m and 21 m) and three trailered vessels. A range of diving gear, oceanographic instruments and sampling equipment is used. It also has aquaria, wet laboratories, an aquaculture centre and public aquaria.

8.1.4 Schools

Most schools with access to the coast will conduct field trips as part of their science curriculum, which involve surveys and possibly sampling and collection of marine organisms.

Queen Charlotte College, Picton, has an Aquaculture Academy, set up in 2002 in partnership with the New Zealand Marine Farming Association (http://qcc.school.nz/aquaculture/). The academy offers students courses in aquaculture and the opportunity to achieve the National Certificate in Seafood (Aquaculture) and qualification in diving and boating. Year 13 students undertake field and laboratory research projects in collaboration with the mussel and salmon industries. The college has a wet laboratory with recirculating aquaria. It also operates a barge (<10 m) that is kept at berth in Picton Marina.

8.1.5 Commercial aquaria

There are at least five commercial aquaria currently operating in New Zealand, all of which include educational and, in some cases, research components in their work.

- Kelly Tarlton's Sea Life Aquarium (Auckland).
- National Aquarium of New Zealand (Napier) (the Marineland dolphinarium closed permanently in 2008).
- Seahorse World (Picton).
- Southern Encounters Aquarium and Kiwi House (Christchurch).
- University of Otago Marine Studies Centre Aquarium (Portobello: currently closed to the public but the aquaria are still stocked and operational).

8.2 Modes of infection

8.3 Vessels

8.3.1 Bilges and other water-containing spaces

See the discussion in Sections 3.4.2., 4.5, 5.5.2, and 6.1.1.

8.3.2 Hull biofouling

See the discussion in Sections 3.4.3 and 5.5.3.

8.3.3 Containment/contaminants

See Sections 4.3.2 and 7.1.5.

8.4 Structures

8.4.1 Instrument moorings

Oceanographic instruments, such as current meters, are generally deployed on moorings consisting of anchors, bottom rope, mooring rope and surface and sub-surface buoys. They may be deployed continuously for several months and acquire extensive fouling.

8.5 Aquaria

Harmful marine organisms may be spread from aquaria by discharge of stock, propagules or pathogens in water from aquaria via flow-through systems, and by accidental or deliberate direct (to natural waterways) or indirect (to stormwater drains, etc.) discharge from recirculating systems (see also Section 7.5).

8.6 Diving equipment

See Section 7.4. and Section 6.1.

8.7 Sampling equipment

Grabs, corers and dredges may retain sediment, seaweed and other organisms after deployment, retaining them in an enclosed, often damp environment where organisms may survive transport to other locations. Similar risks from nets and traps were discussed in Sections 5.5.4. and 7.11.

8.8 Experimental studies with non-indigenous species

Movement and holding of Unwanted Organisms requires permission from MPI (see Section 8.14).

To date most examples of field experiments with non-indigenous species have involved studies in locations where the species is already present. For example, NIWA has conducted field experiments with the crab *Charybdis japonica* in the Waitemata Harbour, *Eudistoma elongatum* in the Bay of Islands and *Sabella spallanzanii* in Lyttelton Harbour and the University of Waikato is soon to begin studies of recruitment of *Undaria pinnatifida* in Tauranga Harbour (Chris Battershill, University of Waikato, pers. comm.).

There have been a few instances of field experiments conducted in locations where the species is not present. For example, Leigh Marine Laboratory used *Charybdis japonica* in field enclosure experiments at sites where it is not currently present (Richard Taylor, Leigh Marine Laboratory, pers. comm.). NIWA scientists have moved the colonial ascidian *Eudistoma elongatum* from Northland to aquaria at their Nelson campus for laboratory studies of larval behaviour (see Section 8.14 for a discussion of measures used in these studies to reduce risk of establishment of the species at these new locations).

Experiments involving the translocation of fouled panels or other structures are likely to include non-indigenous species, given the widespread distribution of many of these species in New Zealand's coastal zone. Translocation may provide a chemical or physical stimulus causing transferred organisms to release propagules in the new location (Apte et al. 2000). Similarly, disturbance or manipulation of reproductively mature individuals in the field may result in spawning.

Aquaculture research may involve the holding and translocation of non-indigenous species, or indigenous species outside their natural range. Modes of infection include release of propagules from holding facilities directly or indirectly into natural waterways or by transfer to on-growing facilities on experimental or commercial marine farms. Dive gear, boats and other equipment used in research may transfer harmful organisms among farms (as described in Section 6). Personnel may also transfer organisms via skin and clothing.

8.9 Available practices to reduce risk – research vessels

In general, the measures and considerations described in Sections 3, 4, 5, and 6 for treatment of ballast water, bilge and biofouling on larger commercial vessels, and in Section 7 for smaller, trailered vessels will also apply to vessels used in the Research and Education sector. Like other commercial vessels, research vessels must operate under a safety management system administered by Maritime New Zealand that requires regular inspection of the vessel's subsurface structure.

8.9.1 Bilges and other water-containing spaces

See Sections 3.8 and 7.8

8.9.2 Hull biofouling

See Sections 3.9 and 7.1.4.

8.9.3 Containment/contaminants

See Sections 4.10, 5.12 and 7.11.

8.10 Available practices to reduce risk – structures

Instrument moorings

Instruments are generally cleaned of fouling to allow data to be downloaded and for instrument maintenance, and then stored in dry conditions. Moorings may be cleaned by water-blasting with fresh or seawater and drying. In cases where redeployment occurs soon after recovery (possibly at a new location), however, there may not be time to clean and dry instruments and moorings adequately.

In circumstances where biosecurity risk is particularly high, soaking of smaller equipment in bleach, vinegar or other disinfectant would provide effective, rapid treatment. We are not aware of this being done as standard practice at present.

Effectiveness

Removal of instrument moorings from the water and cleaning them using pressure water-blasting followed by drying is usually an effective way of removing biofouling and other organisms, provided sufficient time is allowed for drying to occur.

Feasibility and cost of compliance

In most circumstances this practice is feasible. Instrument moorings are typically lifted onto and off vessels using winches or other heavy lifting devices and may be cleaned on board the attendant vessel or (more commonly) onshore. Difficulties (and extra cost) are encountered with very large pieces of experimental infrastructure that cannot be removed from the water easily (e.g., experimental wave energy devices, experimental rafts, etc.).

Expected rate of uptake

Uptake is expected to be high since efficient operations of instruments on the moorings requires them to be cleaned at regular intervals.

8.11 Available practices to reduce risk - aquaria

Recirculating systems pose limited risk of release and the water is usually continuously filtered to remove excess metabolites, which will also remove any organisms or propagules in the water. When aquaria are emptied, water should be treated (with, for example, bleach, ultra-violet radiation or high temperature) and / or discharged to sewer or other treatment system, rather than directly or indirectly to natural waterways. For example, water should not be drained to storm drains that discharge to natural waterways, particularly where the facility is located near the coast, as most marine laboratories are. Aquaria, filters, chillers and other infrastructure are commonly cleaned with disinfectants (such as Halamid®: Charmaine Gallagher, NMIT, pers. comm.) after emptying.

Flow-through systems represent a potentially higher risk and discharged water requires treatment to manage this. Appropriately maintained filters will remove propagules of risk organisms larger than the filter pore size. A pore size of 60 µm was recommended by McClary and Nelligan (2001) to contain all mature organisms and the majority of propagules for 43 target species in their guidelines for hull-cleaning facilities. This pore size has been adopted in the MPI’s guidance document for standards for facilities for the removal of biofouling from vessels that have arrived in New Zealand from overseas (Ministry of Agriculture and Forestry 2011). For in-water cleaning, where environmental conditions may be more conducive to propagule survival, Morrisey et al. (2013) recommended a filter pore size of 2 µm. Alternatively, water may be treated to kill organisms, for example with bleach, high temperature or ultra-violet radiation.

Where aquarium facilities are more than 100 m from the sea or from a natural waterway or drainage system to the sea, water may be discharged to the ground if the soil is sufficiently permeable to absorb all discharged water and there is no likelihood that it could flow back to the sea within two days (consistent with MPI’s standards for facilities for the removal of biofouling from vessels).

Effectiveness

For flow-through aquaria that discharge back into the sea, treatment of intake and discharge streams using filters and sterilisation methods (e.g., ozone, ultra-violet irradiation or temperature) will remove most risk to the surrounding environment.

Disposal of risk species from aquaria should be done in a way that no organisms or propagules can enter natural waterways either directly or indirectly. Lower-risk material can be disposed of to conventional landfill or sewer, but high-risk material may require handling as a biohazard and sent to specialist disposal facilities. Material can also be rendered non-viable by immersion in a chemical sterilising agent, such as formalin, autoclaving or by high-temperature incineration.

Feasibility and cost of compliance

The cost of installing filtration and sterilisation equipment will depend on the size of the facility, its purpose and the volume of water used by it. For example, the Bream Bay Aquaculture Park has two forms of filtration system on its intake stream: one with a two-stage fine filtration grade (55 µm followed by a granular filter battery of 10 µm) and a low flow rate (150 $m^3.h^{-1}$), and the other with a high flow rate and filtration to 55 µm (Anon. 2005).

Expected rate of uptake

Many of these practices (i.e., treatment of discharge streams from large aquarium facilities and appropriate disposal of biological waste) are already implemented by institutions involved in aquaculture research and hatchery production to ensure the health of the stock (See Section 8.14.1). They may not be present in aquarium facilities that are involved primarily in ecological or other marine research.

8.12 Available practices to reduce risk - diving gear

See Sections 5.12, 6.9, and 7.12.

The requirement for dive gear to be sterilised prior to use can be imposed by the Department of Conservation as a condition of permits to collect from marine reserves (Richard Taylor, Leigh Marine Laboratory, pers. comm.). We are not aware of any instances where this provision has been implemented in marine environments.

8.13 Available practices to reduce risk - sampling equipment

Equipment such as grabs, corers, nets, traps and dredges are commonly cleaned by rinsing with seawater on board ship or with freshwater on shore, although they may be deployed in more than one location in between. Washings on board vessels will typically be captured on deck or drain into the bilge (See Sections 3.8, 4.5, and 7.8 for options to manage risks from bilge discharges).

In circumstances where biosecurity risk is particularly high, for example, where grabs or corers are used to collect sediment samples where toxic dinoflagellates cysts are present, soaking in bleach, vinegar or other disinfectant would provide effective, rapid treatment. We are not aware of this being done as standard practice at present and, as with other modes of infection, awareness of the risks is a critical requirement.

8.14 Available practices to reduce risk - experimental studies with non-indigenous species

International Measures

The U.S. Aquatic Nuisance Species Task Force (ANSTF) has developed a risk analysis protocol to ensure that research activities do not result in the introduction or spread of aquatic non-indigenous species (Aquatic Nuisance Species Task Force 2010a)[69]. The protocol applies to research on any aquatic non-indigenous species and is not restricted to “nuisance” non-indigenous species. The Principal Investigator (PI) of the proposed research is required to complete a risk assessment (Part I) to evaluate the potential for the research to result in the introduction or spread of aquatic non-indigenous species. If risk is identified then the PI must specify and describe the ‘Standard Operating Procedures’ (SOP) that will be used throughout the research project to prevent escape or unintentional transfer of the organisms (i.e., a Risk Management Plan - Part II). The SOP must document the following.

- The methods for control and containment that will be used during research and throughout the time that the species is present and viable - this will usually be accomplished by developing appropriate Containment Plans.
- A training plan to ensure that staff associated with the research are aware of the Containment Plan and the SOP for conducting the research.
- A plan showing how, upon completion of the study, the research organisms will be humanely euthanised and disposed of.

[69] http://anstaskforce.gov/research.php

The results of the assessment are then communicated to the external funding agency as part of the proposal and funding process.

A corresponding protocol has been developed by ANSTF for proposals to use non-indigenous species in science and engineering fairs or for other educational purposes (Aquatic Nuisance Species Task Force 2010b).

Domestic measures

Section 52 of the Biosecurity Act 1993 makes it an offence to "*knowingly communicate, cause to be communicated, release, or cause to be released, or otherwise spread any pest or unwanted organism*". An exception is made for scientific research that is carried out with the Authority of the Minister. Scientists wishing to undertake research on unwanted organisms that involves their release or which could potentially lead to their release and spread, or regional councils wishing to exhibit an unwanted organism must apply to MPI for permission. The applicant is required to provide the following information.

- A description of the characteristics of the organisms, including any adverse effects it may have.
- The life stages to be used in the research.
- Its status as a new or notifiable organism or inclusion in any Regional or National Pest Management Strategy.
- Reasons for the research (including benefits to biosecurity).
- Details of how the organism will be obtained, transported, contained and disposed of.
- The risk of escape and establishment.
- Any consultation undertaken with potentially affected parties (Ministry for Primary Industries 2012b).

MPI has recently (2012) issued a general permission to undertake research and/or exhibition of *Styela clava*, *Sabella spallanzanii* and/or *Undaria pinnatifida* (Herrera & Chief Technical Officer 2012). The permission contains conditions that must be met by the research to prevent release and escape of the organism.

Work on marine pathogens and other harmful microbial organisms, new and genetically-modified organisms has to be done in a MPI-approved containment or transitional facility. MPI and the Environmental Protection Agency (EPA) have developed standards for containment facilities such as laboratories, glasshouses and animal facilities that must be met for research on new organisms and microorganisms[70][71]. The standards cover containment, training of staff, storage of material, and treatment and disposal of waste and are intended to minimise the risk of release of the organisms to the environment. Facilities are approved to specific Physical Containment (PC) levels (referred to as PC1, PC2, PC3 or PC4). These levels are arranged in order of increasing stringency of operational and structural requirements with PC1 being the least and PC4 the most stringent.

A range of specific measures can be taken to minimise the risk of spreading non-indigenous species in different types of experiments.

- Remove non-indigenous species from translocated experimental units. Easily-recognised non-indigenous species may be removed before moving

[70] http://www.epa.govt.nz/new-organisms/find-application-form/all-applications/Pages/approved-containment-facility.aspx
[71] http://www.biosecurity.govt.nz/regs/trans/stds

experimentally-fouled structures (such as fouling panels) to locations where the species is not present. This may not be possible for species for which identification or removal is difficult (e.g., microscopic stages of organisms). When high-risk species are known to be present in the source location, transfer to uninfected locations is obviously undesirable.

- Use one sex in experimental studies. The risk of establishment by non-indigenous species that have separate sexes (gonochoric) can be reduced by using only one sex in experimental studies. This is only feasible where sex can be reliable determined and does not change during the life of an organism (as it does in many invertebrates and fish).

Management of risks from laboratory-based studies in which non-indigenous species are held alive in aquaria is discussed above (see Section 8.5). Disposal of risk species should be done in such a way that no organisms or propagules can enter natural waterways either directly or indirectly. Lower-risk material can be disposed of to conventional landfill or sewer, but high-risk material may require handling as a biohazard and sent to specialist disposal facilities. Material can also be rendered non-viable by immersion in a chemical sterilising agent, such as formalin, autoclaving or by high-temperature incineration.

Risks associated with holding and movement of aquaculture species for research are covered under the Aquaculture pathway (Section 6).

Effectiveness

At present, research and educational institutes are only required to develop risk management plans for research or display of declared pests or unwanted organisms (as defined in the Biosecurity Act 1993) or when the research involves potentially harmful microbial organisms, new organisms (as defined by the Hazardous Substances and New Organisms Act 1996; HSNO Act 1996) or genetically-modified organisms. In these instances, written approval is required from the Chief Technical Officer (on behalf of the Minister for Biosecurity) before the research can proceed. Failure to obtain the necessary approval can result in significant penalties. There are no formal requirements or approvals needed for research on other non-indigenous marine species that are present in New Zealand. Few institutes appear to have developed their own protocols governing experiments on non-indigenous marine species and there is patchy awareness within the organisations of practices needed to reduce the risk of spread (Section 8.14.1).

Requiring to consider the risks associated with their research formally and to develop strategies to reduce the likelihood that they will introduce or spread non-indigenous marine organisms into new areas is an effective way of mitigating risk, particularly when failure to do so results in penalty or is linked to permission or funding for the research.

Feasibility and cost of compliance

There are currently no clear mechanisms to implement a universal approvals system for research proposals that would consideration of the risks of spreading non-indigenous marine organisms. Most research organisations have ethics policies for research involving human subjects or animals (and in some cases, for research involving the importation or development of new organisms) that require research proposals to gain approval from a committee before they can proceed. Similar policies could be encouraged for non-indigenous species. The costs associated with implementing such policies involve the time required to develop and review the proposals (e.g., formation of assessment committees) and the costs of implementing any mitigation strategies in the research.

Expected rate of uptake

Compliance is likely to be high for research proposals that involve non-indigenous organisms where there is currently a legal requirement (under the Biosecurity Act 1993 or HSNO Act 1996) to consider the risks of introduction or spread. Uptake of similar measures for other non-indigenous marine organisms will require research organisations to develop and implement their own internal policies.

8.14.1 Existing practices at Crown Research Institutes and other science providers

The National Institute of Water and Atmospheric Research Ltd (NIWA)

Both of NIWA's ocean-going vessels (*Tangaroa* and *Kaharoa*) are now inspected in-water at intervals as close to 3-monthly as voyage schedules permit. NIWA divers do a systematic search of the hull and waterlines of both vessels, paying particular attention to niche areas (such as prop, rudder, acoustic equipment, seawater intakes). Photographs and specimens are taken and a brief summary of findings completed and submitted to the vessels company. All specimens that are removed are identified by taxonomists. To date nothing has been found on either vessel that would require mitigation on a scale that would interfere with vessel operations. The most recent inspection of the *Kaharoa* found *Undaria* and options for removal were discussed with a commercial diving company. In this instance, *Kaharoa* was due to be dry-docked about four months later so slipping the vessel and cleaning it was not an option at the time and in-water hand-removal was employed. Other NIWA vessels that are kept on mooring are not currently part of this inspection programme.

There are no codes of practice for cleaning of trailered vessels, but these are generally washed down inside and outside with freshwater either at the boat ramp or at their home campus. Dive gear and sampling equipment is also washed with freshwater on campus, although during prolonged field work it may be used at more than one location without rinsing in between.

All equipment, including boats and dive gear, used for Marine High Risk Site Surveillance surveys are washed with freshwater and dried before being packed and sent on to the next port. Separate sets of sampling gear (traps, benthic sleds, anchors, ropes and buoys) are used for surveys in the North and South Islands, though dive gear is moved between islands.

Awareness of biosecurity risks varies among different research groups within NIWA and general operating procedures and codes of practice for field work will be developed in the future.

NIWA has containment and transitional facilities for risk items at the following campuses.

- NIWA Hamilton has containment & transitional facilities able to hold biological samples including invertebrates.
- NIWA Mahanga Bay has containment and transitional facilities able to hold biological samples (the Mahanga Bay facility is in the process of closure),
- NIWA Greta Point has containment and transitional facility for microorganisms and cell cultures.
- NIWA Christchurch has transitional and containment facility for microorganisms and cell cultures.

NIWA has also established an aquatic disease investigation and challenge unit at its Greta Point campus (Wellington). The disease investigation unit was designed to provide for disease challenge trials, fish feeding trials to test orally delivered treatments, and vaccine efficacy trials. It has aquarium facilities capable of running small, fully replicated challenge trials for aquaculture species. The laboratory is certified to Physical Containment (PC) 2 standard for containment of microorganisms. Incoming seawater is filtered through two micron filters and UV irradiation to maintain high quality. Outgoing water is treated with ozone to maintain disease security during trials involving pathogens.

Specimens of the introduced ascidian *Eudistoma elongatum* held at the Nelson campus for trials of larval survival were kept in isolated recirculating aquaria. All material was disposed of to landfill at the end of the study and the water from the aquaria was discharged to the sewer.

Water used by OceaNZ Blue Ltd for paua farming at Bream Bay is obtained from an offshore intake and is filtered to 10 µm and irradiated with ultra-violet light.

Plant and Food Research Ltd

No information was available to us at the time of writing

Cawthron Institute

The Cawthron Aquaculture Park is in the process of developing an overarching biosecurity management plan, which will incorporate all tenants (Aurelie Castinel, Cawthron Institute, pers. comm.). Within this plan, individual tenants will develop their own codes of practice and operating procedures to comply with the plan.

The Cawthron Institute currently have internal standard operating procedures for shellfish held in their own facilities at the aquaculture park. Adult mussels brought into the facility are scrubbed and immersed in weak bleach solution to remove fouling. Health checks are done every six months for each shellfish species, including PCR tests for oyster herpes virus.

Protocols were established for handling Pacific oysters after a virus outbreak in North Island oyster farms in 2010. MPI approved the procedures and regularly audits the facility for compliance. Pacific oyster brood-stock are quarantined on arrival. Such oysters have generally been exposed to the virus and offspring are selected for survival rates. All waste seawater from the oyster tanks (spat and brood-stock) in general are treated with ultra-violet light and bleach prior to discharge to the effluent system. Pacific oysters are fed on algae cultured in separate ponds to those for other shellfish species; the seawater supplying these ponds is held for two to three days, which has been reported overseas to reduce survival of the oyster herpes virus. Pacific oyster stock leaving the facility is subject to a health check in accordance with the transfer permit from MPI. Research has shown that there is no vertical transfer of the virus from the brood-stock to larvae. Even so, Pacific oyster spat produced at the aquaculture park is tested for the presence of virus by an approved laboratory (currently MPI) at multiple stages of the hatchery process before release to farmers.

The main Cawthron campus has a containment facility (PC 1 and 2) for microorganisms including microalgae and a transitional facility for other biological material. These are audited annually by MPI.

Water used to hold high-risk organisms in the wet laboratory is heated to 70 °C before being discharged to the sewer. Biological material is placed in biohazard bags that are autoclaved before being placed in a distinct skip for biohazard waste. The content is then transferred to Christchurch where it is treated as ‘special waste” and sent to secure landfill. All users of the laboratory must comply with these procedures.

There is currently no formal policy for dealing with bilge water and other biosecurity hazards associated with field work, but these are identified during pre-trip briefings and procedures identified to minimise risk. Awareness of biosecurity risks varies among different research groups, however, and general operating procedures and codes of practice for field work will be developed in the future (Grant Hopkins, Cawthron Institute, pers. comm.).

Boats, dive and other gear are currently washed down with freshwater after use but on longer field trips may move between locations without washing. The institute's larger vessel (*Waihoi*) has a deck hose and, when engaged in biosecurity-related work, is usually washed down and its bilge flushed with seawater before leaving a work site.

Non-indigenous organisms are not generally moved among locations during field experiments, but where this is necessary the material is inspected visually for high-risk species before transfer.

Field staff working at marine farm sites comply with the farms biosecurity procedures. At present there are no standard procedures for disinfecting gear before moving between farms, but these may be developed in the future.

Samples of species or diseased organisms submitted to the institute by the public or the aquaculture industry are logged and if new or non-indigenous organisms are suspected, they are reported to MPI via the pests and diseases hotline.

8.14.2 Universities and polytechnics

The University of Auckland Leigh Marine Laboratory

The laboratory's 15 m research vessel is kept on a mooring when not in use and is taken out of the water annually for cleaning and renewal of its anti-fouling system (Richard Taylor, Leigh Marine Laboratory, pers. comm.). There is no formal policy of cleaning it prior to work in distant locations but such trips are infrequent. The three trailered boats only work locally.

The laboratory has no formal policy or codes of practice for non-indigenous species, but these are not generally kept in the flow-through aquarium system. Leigh Marine Laboratory has held the crab *Charybdis japonica* in the aquarium and used them in field enclosure experiments at sites where it is not currently present, but using only male crabs to prevent establishment should they escape. Proposed projects involving *Undaria pinnatifida* and *Styela clava* have been rejected for biosecurity reasons (Richard Taylor, Leigh Marine Laboratory, pers. comm.).

University of Waikato

Biosecurity risks are managed through protocols in the Faculty of Science and Engineering's *Code of practice for health and safety in the field*, namely *Microbiological hazards associated in working with water, soil and biological materials* and *Cleaning methods for freshwater activities*. These relate to work in freshwater (the cleaning methods protocol was developed for work on didymo) but are also followed for marine work (Dudley Bell, University of Waikato, pers. comm.).

The University's aquatic laboratory in Hamilton has a quarantine PC1 area and any work with potentially harmful marine organisms would be undertaken there. To date, however, they have not been involved in any such work. Organisms collected for laboratory work are returned to the collection location or disposed of to landfill (Conrad Pilditch, University of Waikato, pers. comm.).

A risk assessment and ethics application will be prepared for the planned work on *Undaria* at the Tauranga Laboratory (Chris Battershill, University of Waikato, pers. comm.). This will be reviewed by the University's ethics committee (which includes members from Waikato Regional Council) and the work will be vetted by Bay of Plenty Regional Council and MPI.

Victoria University of Wellington Coastal Ecology Laboratory (VUCEL)

The Coastal Ecology Laboratory has policies in place to manage risks associated with any potential projects on non-indigenous species, documented in their Operations Manual (available at http://www.victoria.ac.nz/sbs/research-centres-institutes/vucel/resources/operations-manual) (Jeff Shima, Victoria University of Wellington, pers. comm.). The manual contains the following provisions.

- Housing of non-indigenous species within VUCEL facilities requires consultation with the VUCEL Technical Team, and approval from the VUCEL Director. Organisms that fall under the jurisdiction of the SBS Transitional and Containment Facility (i.e., requiring PC2 containment) are not permitted.
- Lab users who wish to house non-indigenous species at VUCEL will need to:
  - prepare a “Safe Method of Use” document that outlines the risks, safe use procedures, and what to do in an "emergency". If approved by the VUCEL Director, this document will be circulated to all users of the facility, and posted next to the hazard (and it should be of sufficient detail and clarity to enable someone not familiar with the specifics of the hazard to respond appropriately in the event of an emergency),
  - design and implement an effective secondary containment (e.g., a primary tank that is contained within a large plastic box), such that if the primary containment failed, the spill would be contained. What to do in the event of a spill should be covered in the Safe Method of Use document.
  - first response items should be kept next to the hazard (e.g., sufficient quantities of bleach kill the hazard in the event of a spill, or when the experiments have finished. The safe use of bleach should also be covered in the Safe Method of Use document).

Nelson Marlborough Institute of Technology

Biosecurity risks related to teaching activities are minimised by developing standard operating practices for each of their facilities at NMIT (freshwater) or at the Cawthron Aquaculture Park (seawater). All visits to farms and hatcheries include biosecurity practices such as wearing gumboots and stepping through dips for biosecurity control (Charmaine Gallagher, NMIT, pers. comm.).

All of NMIT’s aquariums, chillers and filters are dried and cleaned with a combination of hydrogen peroxide and Halamid®. Dive gear is owned by staff and students and is generally cleaned and dried before use.

University of Canterbury

Boating activity at the Kaikoura Marine Laboratory is minimal but the same boat is also used for work around Banks Peninsula (Sharyn Goldstien, University of Canterbury, pers. comm.). The boat is fully flushed and washed with freshwater before transfer between locations. Research at the laboratory does not include any work on harmful marine organisms. Snorkelling gear used during teaching courses is hired from a local supplier, although staff and some students do use their own equipment.

Seawater for aquaria at the main campus is pumped from Lyttelton Harbour but all waste enters the sewage system and is not transferred anywhere else. Staff at the main campus have permission from MPI to work with *Styela clava* in their quarantine room and protocols are in place to manage biosecurity risk for this species. Staff also have permits to run experiments with live Antarctic fish and these samples are transported along Antarctic research pathways. Toxic algae are transferred between Cawthron and the university and protocols are in place for disposal after use.

Moorings for instruments are placed in Lyttelton Harbour but are dried and washed between projects.

8.15 Measures to consolidate biosecurity risk management

8.15.1 Institutional Codes of Practice (CoP)

It is clear from this review that there are marine biosecurity risks associated with a range of activities undertaken within the marine research and education sector in New Zealand. These include direct risks from experimentation with non-indigenous species and indirect risks associated with transport of non-indigenous species on research vessels or equipment. Although there are individual measures that can be taken to mitigate many of these risks, knowledge about them and their management is patchy within institutions and few have well-articulated, overarching policies for biosecurity that cover all of their operations.

Several institutes indicated that they are considering or are working toward voluntary CoPs to cover the whole of their operations, similar to those developed by the aquaculture industry (Section 6.2). This approach should be encouraged within the sector.

Many of these organisations will be familiar with or will have developed their own CoPs for research activities in high value, protected environments. For example, the Secretariat of the Antarctic Treaty has developed a protocol that outlines measures that should be put in place to minimise the risk of impacts from non-indigenous species in the Antarctic (Committee for Environmental Protection 2011). Similarly, Antarctica New Zealand has developed a policy on biosecurity and non-indigenous species that provides guiding principles for its operations in Antarctica (although this does not specifically make mention of marine biosecurity risks, (Antarctica New Zealand 2011).

Effectiveness

At present, consideration of the risks of spreading potentially harmful marine organisms is inconsistent within and among research and education institutes. Development of organisational CoP would require staff within these organisations to evaluate the risks involved in their day-to-day operations and to develop strategies to manage those risks.

Feasibility and costs of compliance

Encouraging the research and education sector to develop operational CoPs to manage biosecurity risks will require an awareness campaign that highlights the legislative and policy requirements of government and the benefits (public good and institutional) that arise from better day-to-day practice. Costs of compliance will vary depending on the size of organisation and the infrastructure or activity that requires management and will potentially range from low (e.g., implementation of simple wash-down protocols for equipment) to high (e.g., more frequent cleaning or dry-docking of large research vessels and equipment). Costs will also involve training/familiarising staff with the CoPs and auditing their implementation.

Expected rate of uptake

We expect that a coordinated national campaign to develop CoPs for marine biosecurity within the research and education sector would achieve good uptake. Audits will be required to determine how well the CoPs are implemented within each organisation.

8.16 Research and education – summary of recommendations

The research and education sectors undertake a range of activities in coastal environments that have the potential to transport harmful marine organisms around New Zealand. These include the use of vessels (trailered and non-trailered) and scientific equipment in field surveys (e.g., diving gear, sampling equipment, and deployed instruments), deliberate movement of equipment or live organisms for experimentation, and the keeping and breeding of organisms in aquaria and hatcheries.

At present, there is no consistent approach within the sector to manage these risks. Knowledge about potentially harmful marine organisms and their management is patchy within institutions and few have well-articulated, overarching policies for biosecurity that cover all of their operations. The sector should be encouraged to consolidate and improve on existing measures by developing institutional CoPs to manage biosecurity risks across their operations. These could include:

- a requirement for risk management plans for ballast water (where applicable), bilge and biofouling for all non-trailered vessels (as recommended for other domestic commercial vessels under SSM),
- wash-down / sterilisation protocols for trailered vessels and mobile equipment (including diving equipment),
- SoPs for field surveys and experimental studies that require assessment of the risks of spreading non-indigenous species (and propose mitigation strategies), and
- SoPs for managing risks from hatchery and aquarium facilities.

Uptake could be encouraged by an awareness campaign at a high level within the organisations (e.g., General Managers of Operations) and by provision of template examples. Training in the CoPs and independent audit will encourage greater uptake of best-practice within the institutions.

9 Acknowledgements

We are grateful to the following for advice used in this report: Andrew Bell, Eugene Georgiades, Melanie Russell and Ron Blackwell (Ministry for Primary Industries), Sarah Hucker and Janice Gravett (Department of Conservation), Scott Speed, Brett Buckland and Bill Trusewich (Auckland Council), Hilke Giles (Environment Waikato), Derek Richards (Environment Southland), Dave Bowden and Nathan Russ (Heritage Expeditions), Kathy Conmee (Northland Underwater Technical Services), Roger Belton (Inshore wild-harvest shellfish sector), Carol Scott (New Zealand Federation of Commercial Fishermen), Colin Johnston (Aquaculture New Zealand), Graeme Coates (New Zealand Marine Farming Association), Alison Undorf-Lay (Sanford Fisheries Ltd), Daryl Sykes (Rock Lobster Industry Council), Mark Gillard (NZ King Salmon Co Ltd), Jeremy Cooper (New Zealand Paua Industry Council), Sol Fergus (NZ Diving & Salvage Ltd), Mike Percy (New Zealand Underwater Association), Stewart Bull (Fiordland Marine Guardians), Peter Lawless (Top of the South Marine Biosecurity Partnership), Richard Taylor (University of Auckland), Chris Battershill, Dudley Bell and Conrad Pilditch (University of Waikato), James Bell and Jeff Shima (Victoria University of Wellington), Charmaine Gallagher (Nelson Marlborough Institute of Technology), Sharyn Goldstien (University of Canterbury), Keith Probert (University of Otago), Aurelie Castinel and Grant Hopkins (Cawthron Institute), Sam Judd (Sustainable Coastlines), Jono Underwood (Marlborough District Council), Dave Duncan (Port Nelson), Steve Hainstock, Paul Sheldon and Lindsay Vaughan (Tasman District Council), Peggy Cunningham-Hales (Greater Wellington Regional Council), Karen Lee and Richard Popenhagen (Nelson City Council).

10 References

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

Akinfiev, T., Janushevskis, A.E.L., 2007. A brief survey of ship hull cleaning devices. *Transport and Engineering Mechanics, 24*, 133-146.

AMOG Consulting. 2002. *Hull fouling as a vector for the translocation of marine organisms. Phase I: Hull fouling research*. Ballast Water Research Series, Report No. 14. Canberra: Department of Agriculture, Fisheries and Forestry Australia. 142 p.

Anon., 2005. Clean water for Bream Bay. *New Zealand Aquaculture, May/June*, 9.

Antarctica New Zealand. 2011. Biosecurity and non-native species. *Health, Safety and Environment Policy – 6* Christchurch: Antarctica New Zealand. 3 p.

Apte, S., Holland, B.S., Godwin, L.S., Gardner, J.P.A., 2000. Jumping ship: a stepping stone event mediating transfer of a non-indigenous species via a potentially unsuitable environment. *Biological Invasions, 2*, 75-79.

Aquaculture New Zealand. 2007. *The Greenshell mussel industry code of practice*. Aquaculture New Zealand. 91 p.

Aquaculture of Western Australia (ACWA). 2013. *Environmental code of practice for the sustainable management of Western Australia's mussel and oyster aquaculture industries*. Aquaculture of Western Australia & W.A. Department of Fisheries, Perth. 38 p.

Aquatic Nuisance Species Task Force. 2010a. *Federal Aquatic Nuisance Species (ANS) research risk analysis protocol*. Aquatic Nuisance Species Task Force, Washington. 19 p.

Aquatic Nuisance Species Task Force. 2010b. *Reducing the risk of introducing or spreading non-indigenous plants, animals and microorganisms through science and engineering fair projects*. Education and Outreach Working Group, Gulf & South Atlantic Regional Panel to the Aquatic Nuisance Species Task Force. 13 p.

Aquenal Pty Ltd 2007. *Pre-developing technology for marine pest emergency eradication response: Review of current technology.* A draft report prepared for the Australian Department of Agriculture, Fisheries and Forestry. Aquenal Pty Ltd, Hobart. 128 p.

Aquenal Pty Ltd. 2009. *Enclosure treatment: A biosecure treatment for oil rig pontoons*. MAF Biosecurity New Zealand Technical Paper No: 2009/40 prepared for MAF Biosecurity New Zealand. Ministry for Agriculture and Forestry, Wellington. 39 p.

Arens, C.J., Paetzold, S.C., Ramsay, A., Davidson, J., 2011. Pressurized seawater as an anti-fouling treatment against the colonial tunicates *Botrylloides violaceus* and *Botryllus schlosseri* in mussel aquaculture. *Aquatic Invasions, 6*, 465-476.

Atalah, J., Bennett, H., Hopkins, G., Forrest, B., 2013. Evaluation of the sea anemone *Anthothoe albocincta* as an augmentative biocontrol agent for biofouling on artificial structures. *Biofouling, 29*, 559-571.

Australian Government. 2009. *National assessment guidelines for dredging*. Commonwealth Department of Environment, Water, Heritage & the Arts. Canberra, Australia. 81 p.

Bakker, J.A., Paetzold, S.C., Quijón, P.A., Davidson, J., 2011. The use of food grade oil in the prevention of vase tunicate fouling on mussel aquaculture gear. *Management of Biological Invasions, 2*, 15-25.

Barry, S.C., Hayes, K.R., Hewitt, C.L., Behrens, H.L., Dragsund, E., Bakke, S.M., 2008. Ballast water risk assessment: principles, processes, and methods. *ICES Journal of Marine Science, 65*, 121-131.

Bay of Plenty Regional Council. 2011. *Moorings newsletter*. Bay of Plenty Regional Council Tauranga. 3pp.

Beca Infrastructure Ltd. 2012. *Auckland recreational boating study*. A report prepared for Auckland Council by Beca Infrastructure Ltd, Auckland. 36 p.

Bell, A., Phillips, S., Georgiades, E., Kluza, D., 2011. *Risk analysis: vessel biofouling.* A report prepared by the Policy and Risk Directorate, MAF Biosecurity New Zealand. Ministry for Agriculture and Forestry, Wellington. 155 p.

Bilbao, A., Nunez, J., Del Pino Viera, M., Sosa, B., Fernandez-Palacios, H., Maria Hernandez-Cruz, C., 2011. Control of shell-boring polychaetes in *Haliotis tuberculata* coccinea (Reeve 1846) aquaculture: species identification and effectiveness of Mebendazole. *Journal of Shellfish Research, 30*, 331-336.

Biodiverse Limited. 2010. *Slowing pest spread: domestic pathways of human mediated pest spread and opportunities for their management*. MAF Biosecurity New Zealand Technical Paper No: 2010/22 prepared for MAF Biosecurity New Zealand. Ministry for Agriculture and Forestry, Wellington. 69 p.

Blake, J., 1999. Overcoming the 'value–action gap' in environmental policy: tensions between national policy and local experience. *Local Environment, 4*, 257-278.

Blakemore, K.A., Forrest, B.M., 2007. *Heat treatment of marine fouling organisms*. Cawthron Report No. 1300. Prepared for Golder Associates (NZ) Ltd. Cawthron Institute, Nelson. 50 p.

Bohlander, J., 2009. *Review of options for in-water cleaning of ships*. MAF Biosecurity New Zealand Technical Paper No: 2009/42. Prepared for MAF Biosecurity New Zealand. Ministry for Agriculture and Forestry, Wellington. 34 p.

Braithwaite, R.A., Carrascosa, M.C.C., McEvoy, L.A., 2007. Biofouling of salmon cage netting and the efficacy of a typical copper-based antifoulant. *Aquaculture, 262*, 219-226.

Braithwaite, R.A., McEvoy, L.A., 2005. Marine biofouling on fish farms and its remediation. In A. J. Southward, P. A. Tyler, C. M. YoungL. A. Fuiman (Eds.), *Advances in Marine Biology, Vol 47*, pp. 215-252.

Branch, G.M., Steffani, N.C., 2004. Can we predict the effects of alien species? A case-history of the invasion of South Africa by *Mytilus galloprovincialis* (Lamarck). *Journal of Experimental Marine Biology and Ecology, 300*, 189-215.

Briski, E., Wiley, C.J., Bailey, S.A., 2012. Role of domestic shipping in the introduction or secondary spread of non-indigenous species: biological invasions within the Laurentian Great Lakes. *Journal of Applied Ecology, 49*, 1124-1130.

Cahill, P., Heasman, K., Jeffs, A., Kuhajek, J., Mountfort, D., 2012. Preventing ascidian fouling in aquaculture: screening selected allelochemicals for anti-metamorphic properties in ascidian larvae. *Biofouling, 28*, 39-49.

California State Lands Commission. 2012a. *Amendment to Article 4.8: Biofouling Regulations for Vessels Operating in California Waters (Updated November 16,2012)*. Sacramento, California: California State Lands Commission.

California State Lands Commission. 2012b. *Proposed rulemaking: amendment to Article 4.8: Biofouling Regulations for Vessels Operating in California Waters* <Retrieved 5/04/2013, from http://www.slc.ca.gov/spec_pub/mfd/ballast_water/Laws_Regulations.html>

Carlton, J.T., 2001. *Introduced species in U.S. coastal waters: environmental impacts and management priorities.* A report prepared for the Pew Oceans Commission. Arlington, Virginia. U.S.A. 29 p.

Carlton, J.T., Scanlon, J.A., 1985. Progression and dispersal of an introduced alga: *Codium fragile* spp. *tomentosoides* (Chlorophyta) on the Atlantic coast of north America. *Botanica Marina, 28*, 155-165.

Carver, C.E., Chisholm, A., Mallet, A.L., 2003. Strategies to mitigate the impact of *Ciona intestinalis* (L.) biofouling on shellfish production. *Journal of Shellfish Research, 22*, 621-631.

Castle, C., 2013. Snapshot - Chatham Rock Phosphate Limited. Chatham Rock Phosphate Ltd, *www.rockphosphate.co.nz*. Takaka, New Zealand. 2 p.

Cawthron Institute. 2013. *Biosecurity guidelines for managing seawater discharges from vessels operating in the Fiordland (Te Moana o Atawhenua) Marine Area*. A report prepared by the Cawthron Institute on behalf of the Ministry for Primary Industries. Cawthron Institute, Nelson, New Zealand. 15 p.

Centre for Advanced Engineering. 2003. *Economic opportunities in New Zealand's oceans - informing the development of Oceans Policy*. A report prepared for the Oceans Policy Secretariat. Centre for Advanced Engineering, University of Canterbury, Christchurch. 32 p.

Centre for International Economics. 2007. *Ballast water management - a Regulation Impact Statement*. Final report prepared for the Department of Agriculture Forestry and Fisheries. Centre for International Economics, Canberra. 80 p.

Chiswell, S.M., Inglis, G.J., Hayden, B., 2001. *Alternative biosecurity management tools for vector threats: ballast water discharge and exchange areas.* Final Research Report. Prepared for Ministery of Fisheries Research Project ZBS2000/02, Objectives 1, 2 & 3. NIWA, Wellington, New Zealand. 32 p.

Christie, A.B., Barker, R.G., 2007. *Mineral resource assessment of the Northland Region, New Zealand*. GNS Science Report 2007/06. GNS Science Ltd., Lower Hutt. 179 p.

Clearwater, S.J., Hickey, C.W., 2003. *A review of potential pesticides for controlling aquatic pest species in New Zealand*. NIWA Client Report No. HAM2003-139, produced for Department of Conservation. NIWA, Hamilton, New Zealand. 69 p.

Colmar Brunton Ltd. 2011. *Boat ownership, safety, and life jacket campaign research 2011 (online summary)*. A report prepared for Maritime New Zealand. Colmar Brunton, Wellington. 29 p.

Committee for Environmental Protection. 2011. *Non-native species manual*. Secretariat of the Antarctic Treaty, Buenos Aires, Argentina. 32 p.

Commonwealth of Australia. 2009a. *National biofouling management guidance for commercial fishing vessels*. The National System for the Prevention and Management of Marine Pest Incursions. Commonwealth of Australia, Canberra. 16 p.

Commonwealth of Australia. 2009b. *National Biofouling Management Guidance for Recreational Vessels*. The National System for the Prevention and Management of Marine Pest Incursions. Commonwealth of Australia, Canberra. 16 p.

Commonwealth of Australia. 2009c. *National Biofouling Management Guidance for the Petroleum Production and Exploration Industry*. The National System for the Prevention and Management of Marine Pest Incursions. Commonwealth of Australia, Canberra. 56 p.

Costello, C., Drake, J.M., Lodge, D.M., 2007. Evaluating an invasive species policy: ballast water exchange in the Great Lakes. *Ecological Applications, 17*, 655-662.

Coutts, A., Forrest, B., 2005. *Evaluation of eradication tools for the clubbed tunicate Styela clava*. Cawthron Report No. No. 1110. Cawthron Institute, Nelson, New Zealand. 48 p.

Coutts, A., Taylor, M.D., 2004. A preliminary investigation of biosecurity risks associated with biofouling of merchant vessels in New Zealand. *New Zealand Journal of Marine and Freshwater Research, 38*, 215-229.

Coutts, A.D.M., Dodgshun, T.J., 2007. The nature and extent of organisms in vessel sea-chests: A protected mechanism for marine bioinvasions. *Marine Pollution Bulletin, 54*, 875-886.

Coutts, A.D.M., Forrest, B.M., 2007. Development and application of tools for incursion response: Lessons learned from the management of the fouling pest *Didemnum vexillum*. *Journal of Experimental Marine Biology and Ecology, 342*, 154-162.

Coutts, A.D.M., Moore, K.M., Hewitt, C.L., 2003. Ships' sea-chests: an overlooked transfer mechanisms for non-indigenous marine species? *Marine Pollution Bulletin, 46*, 1504-1515.

Coutts, A.D.M., Valentine, J.P., Edgar, G.J., Davey, A., Burgess-Wilson, B., 2010. Removing vessels from the water for biofouling treatment has the potential to introduce mobile non-indigenous marine species. *Marine Pollution Bulletin, 60*, 1533-1540.

Cruise New Zealand. 2010. New Zealand: The cruise destination of choice in the South Pacific. Available online at http://www.cruisenewzealand.org.nz/. Retrieved 23/08/2010

Culver, C.S., Kuris, A.M., 2000. The apparent eradication of a locally established introduced marine pest. *Biological Invasions, 2*, 245-253.

Dafforn, K.A., Lewis, J.A., Johnston, E.L., 2011. Anti-fouling strategies: history and regulation, ecological impacts and mitigation. *Marine Pollution Bulletin, 62*, 453-465.

Dahlstrom, M., Martensson, L.G.E., Jonsson, P.R., Arnebrant, T., Elwing, H., 2000. Surface active adrenoceptor compounds prevent the settlement of cyprid larvae of *Balanus improvisus*. *Biofouling, 16*, 191-203.

Dakin, W.J., 1952. *Australian seashores*. Sydney, Australia: Angus & Robertson Ltd.

Darbyson, E., Locke, A., Hanson, J.M., Willison, J.H.M., 2009a. Marine boating habits and the potential for spread of invasive species in the Gulf of St. Lawrence. *Aquatic Invasions, 4*, 87-94.

Darbyson, E., Locke, A., Hanson, J.M., Willison, J.H.M., 2009b. Vectors of local dispersal of marine and estuarine invasive species in the southern Gulf of St Lawrence, Canada. *Aquatic Invasions, 4*, 87-94.

David, M., Gollasch, S., 2008. EU shipping in the dawn of managing the ballast water issue. *Marine Pollution Bulletin, 56*, 1966-1972.

David, M., Gollasch, S., Cabrini, M., Perkovic, M., Bos?njak, D., Virgilio, D., 2007. Results from the first ballast water sampling study in the Mediterranean Sea - the Port of Koper study. *Marine Pollution Bulletin, 54*, 53-65.

de Ronde, C.E.J., Baker, E.T., Massoth, G.J., Lupton, J.E., Wright, I.C., Sparks, R.J., et al., 2007. Submarine hydrothermal activity along the mid-Kermadec Arc, New Zealand: Large-scale effects on venting. *Geochemistry, Geophysics, Geosystems, 8*, Q07007.

Denny, C.M., 2008. Development of a method to reduce the spread of the ascidian *Didemnum vexillum* with aquaculture transfers. *ICES Journal of Marine Science, 65*, 805-810.

Derraik, J., Phillips, S., 2010. Online trade poses a threat to biosecurity in New Zealand. *Biological Invasions, 12*, 1477-1480.

Dodgshun, T.J., Taylor, M.D., Forrest, B.M., 2007. *Human-mediated pathways of spread for non-indigenous marine species in New Zealand*. DOC Research & Development Series 266. Department of Conservation, Wellington, New Zealand. 44 p.

Drake, L.A., Ruiz, G.M., Galil, B.S., Mullady, T.L., Friedmann, D.O., Dobbs, F.C., 2002. Microbial ecology of ballast water during a transoceanic voyage and the effects of open-ocean exchange. *Marine Ecology Progress Series, 233*, 13-20.

Dromgoole, F.I., 1975. Occurence of *Codium fragile* subspecies *tomentosoides* in New Zealand waters. *New Zealand Journal of Marine & Freshwater Research, 9*, 257-264.

Drury, K.L.S., Rothlisberger, J.D., 2008. Offense and defense in landscape-level invasion control. *Oikos, 117*, 182-190.

Duggan, I.C., Rixon, C.A.M., MacIsaac, H.J., 2006. Popularity and propagule pressure: determinants of introduction and establishment of aquarium fish. *Biological Invasions, 8*, 377-382.

Dunmore, R., Piola, R., Hopkins, G., 2011. *Assessment of the effects of household cleaners for the treatment of marine pests*. MAF Technical Paper No: 2011/11 prepared for the Ministry of Agriculture and Forestry, Wellington. 46 p.

Elston, R.A., 1997. *Pathways and management of marine non-indigenous species in the shared waters of British Columbia and Washington*. A report prepared for Puget Sound Water Quality Authority, U.S. Environmental Protection Agency, Region 10 and the Department of Fisheries and Oceans, Canada. 50 p.

Environment Canterbury. 2006. *Swing moorings: information on construction and maintenance*. Environment Canterbury, Christchurch. 16 p.

EPA Victoria. 2010. *Domestic ballast water management in Victorian state waters*. Protocol for Environmental Management. EPA Victoria, Carlton, Victoria, Australia. 13 p.

ES Link Services Pty Ltd. 2013. *Report 1. In-water hull cleaning and filtration system: in-water cleaning trials*. Fisheries Occasional Publication No. 114. Western Australia Department of Fisheries. Government of Western Australia, Perth, Western Australia. 44 p.

Fish Safe. 2003. *Stability Handbook*. Fishing Industry Safety and Health (Fish Safe). Vancouver, Canada. 60 p.

Fisheries Research and Development Corporation. 2011. *Final report - OsHV-1 µVar (Ostreid herpesvirus-1 µVar).* Summary of Findings from an International Workshop on OsHV-1 µVar, Cairns, Queensland, Australia. Fisheries Research and Development Corporation, Canberra, Australia. 101 p.

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

Floerl, O., Coutts, A., 2011. *Feasibility of using remote opertated vehicles (ROVs) for vessel biofouling inspections*. NIWA Client Report No. 2010-073, prepared for Western Australia Department of Fisheries Project DoF 10/2011. NIWA, Christchurch. 48 p.

Floerl, O., Inglis, G.J., Dey, K., Smith, A., 2009. The importance of transport hubs in stepping-stone invasions. *Journal of Applied Ecology, 46*, 37-45.

Floerl, O., Inglis, G., Hayden, B., 2005. A risk based predictive tool to prevent accidental introductions of marine non-indigenous species. *Environmental Management, 35*, 765-768.

Floerl, O., Peacock, L., Seaward, K., Inglis, G., 2010. *Review of biosecurity and contaminant risks associated with in-water cleaning.* A report commissioned by the Department of Agriculture, Fisheries and Forestry (DAFF). Commonwealth of Australia. 136 p.

Floerl, O., Smith, M., Inglis, G., Davey, N., Seaward, K., Johnston, O., et al., 2008. *Vessel biofouling as a vector for the introduction of non-indigenous marine species to New Zealand: recreational vessels*. NIWA Client Report prepared for MAF Biosecurity New Zealand Research Project ZBS2004/03. NIWA, Christchurch. 103 p.

Forrest, B., 2013. *Vessel hull fouling as a marine biosecurity indicator in the Top of the South: 2013 survey*. A report prepared for the Top of the South Marine Biosecurity Partnership Nelson: Marine Biologic Ltd., Nelson. 27 p.

Forrest, B., Blakemore, K.A., 2002. *Inter-regional marine farming pathways for the Asian kelp Undaria pinnatifida*. Cawthron Report No. 726. Cawthron Institute, Nelson. 27 p.

Forrest, B., Blakemore, K.A., 2006. Evaluation of treatments to reduce the spread of a marine plant pest with aquaculture transfers. *Aquaculture, 257*, 333-345.

Forrest, B., Hopkins, G., Webb, S., Tremblay, L., 2011. *Overview of marine biosecurity risks from finfish aquaculture development in the Waikato Region*. Waikato Regional Council Technical Report 2011/22. Cawthron Institute, Nelson. 78 p.

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

Forrest, B.M., Brown, S.N., Taylor, M.D., Hurd, C.L., Hay, C.H., 2000. The role of natural dispersal mechanisms in the spread of *Undaria pinnatifida* (Laminariales, Phaeophyceae). *Phycologia, 39*, 547-553.

Forrest, B.M., Hopkins, G.A., Dodgshun, T.J., Gardner, J.P.A., 2007b. Efficacy of acetic acid treatments in the management of marine biofouling. *Aquaculture 262*, 319-332.

Forrest, B.M., Keeley, N.B., Hopkins, G.A., Webb, S.C., Clement, D.M., 2009. Bivalve aquaculture in estuaries: review and synthesis of oyster cultivation effects. *Aquaculture, 298*, 1-15.

Goldman, J.C., Quinny, H.L., Capuzzo, J.M. 1979. Chlorine disappearance in sea-water. *Water Research*, *13*: 315-323. http://dx.doi.org/10.1016/0043-1354(79)90212-4

Goldstien, S.J., Schiel, D.R., Gemmell, N.J., 2010. Regional connectivity and coastal expansion: differentiating pre-border and post-border vectors for the invasive tunicate *Styela clava*. *Molecular Ecology, 19*, 874-885.

Gollasch, S., David, M., Voigt, M., Dragsund, E., Hewitt, C., Fukuyo, Y., 2007. Critical review of the IMO international convention on the management of ships' ballast water and sediments. *Harmful Algae, 6*, 585-600.

Gollasch, S., Lenz, J., Dammer, M., Andres, H.G., 2000. Survival of tropical ballast water organisms during a cruise from the Indian Ocean to the North Sea. *Journal of Plankton Research, 22*, 923-937.

Grandison, C., Piola, R.F., Fletcher, L., 2012. *A review of marine growth protection systems (MGPS) - options for the Royal Australian Navy*. A report prepared by the Marine Platforms Division, Australian Defence Science and Technology Organisation (DSTO) Fishermens Bend, Victoria. 37 p.

Gray, D.K., Johengen, T.H., Reid, D.F., MacIsaac, H.J., 2007. Efficacy of open-ocean ballast water exchange as a means of preventing invertebrate invasions between freshwater ports. *Limnology and Oceanography, 52*, 2386-2397.

Greene, J.K., Grizzle, R.E., 2007. Successional development of fouling communities on open ocean aquaculture fish cages in the western Gulf of Maine, USA. *Aquaculture, 262*, 289-301.

Grosholz, E., Crafton, R.E., Fontana, R.E., Pasari, J., Williams, S., Zabin, C., 2012. *Aquatic invasive species vector risk assessments: an analysis of aquaculture as a vector for introduced marine and estuarine species in California*. Final report submitted to the California Ocean Science Trust by the University of California at Davis. University of California. 77 p.

Guardiola, F.A., Cuesta, A., Mesegeur, J., Esteban, M.A., 2012. Risks of using anti-fouling biocides in aquaculture. *International Journal of Molecular Sciences, 13*, 1541–1560.

Guenther, J., Fitridge, I., Misimi, E., 2011. Potential anti-fouling strategies for marine finfish aquaculture: the effects of physical and chemical treatments on the settlement and survival of the hydroid *Ectopleura larynx*. *Biofouling, 27*, 1033-1042.

Guenther, J., Misimi, E., Sunde, L.M., 2010. The development of biofouling, particularly the hydroid *Ectopleura larynx*, on commercial salmon cage nets in Mid-Norway. *Aquaculture, 300*, 120-127.

Guo, S., Khoo, B.C., Teo, S.L.M., Lee, H.P., 2013. The effect of cavitation bubbles on the removal of juvenile barnacles. *Colloids and Surfaces B: Biointerfaces, 109*, 219-227.

Guo, S., Lee, H.P., Khoo, B.C., 2011. Inhibitory effect of ultra-sound on barnacle (*Amphibalanus amphitrite*) cyprid settlement. *Journal of Experimental Marine Biology and Ecology, 409*, 253-258.

Guo, S., Lee, H.P., Teo, S.L.M., Khoo, B.C., 2012. Inhibition of barnacle cyprid settlement using low frequency and intensity ultra-sound. *Biofouling, 28*, 131-141.

Gust, N., Floerl, O., Inglis, G., Miller, S., Fitridge, I., Hurren, H., 2005. *Rapid delimitation survey of Styela clava in the Viaduct Harbour and Freemans Bay, Auckland.* NIWA Client Report No. CHC2005-147. Prepared for Biosecurity New Zealand Research Project ZBS 2005-32. NIWA, Christchurch. 52 p.

Gust, N., Inglis, G., Floerl, O., Peacock, L., Denny, C., Forrest, B., 2008. *Assessment of population management trial options for Styela clava at three* *locations*. NIWA Client Report No. CHC2007-094. Prepared for MAF-Biosecurity NZ Project BSP21705 NIWA, Christchurch. 290 p.

Gust, N., Inglis, G., Peacock, L., Miller, S., Floerl, O., Hayden, B., et al., 2006. *Rapid nationwide delimitation surveys for Styela clava.* NIWA Client Report No. CHC2006-24. Prepared for Biosecurity New Zealand Project ZBS2005-32. NIWA, Christchurch. 81 p.

Handley, S.J., Berquist, P.R., 1997. Spionid polychaete infestations of intertidal pacific oysters *Crassostrea gigas* (Thunberg), Mahurangi Harbour, northern New Zealand. *Aquaculture, 153*, 191-205.

Hay, C.H., 1990. The dispersal of sporophytes of *Undaria pinnatifida* by coastal shipping in New Zealand, and implications for further dispersal of *Undaria* in France. *British Phycological Journal, 25*, 301-313.

Hayden, B.J., Unwin, M., Roulston, H., Peacock, L., Floerl, O., Kospartov, M., et al., 2009. *Vessel movements within New Zealand: evaluation of vessel movements from the 24 ports and marinas surveyed through the port baseline survey programmes ZBS2000-04, ZBS2005-18 and ZBS2005-19.* MAF Biosecurity Technical Paper No: 2005-13. NIWA, Christchurch. 269 p.

Hayes, K., 2002. Identifying hazards in complex ecological systems. Part 2: infestation modes and effects analysis for biological invasions. *Biological Invasions, 4*, 251-261.

Hayes, K., Sliwa, C., Migus, S., McEnnulty, F., Dunstan, P., 2005. *National Priority Pests: Part II. Ranking of Australian marine pests*. A report prepared for the Department of Environment and Heritage by CSIRO Marine Research. <Accessible from http://www.marine.csiro.au/crimp/reports/PriorityPestsFinalreport.pdf>, Parkes, ACT, Australia.

Hedge, L.H., O'Connor, W.A., Johnston, E.L., 2012. Manipulating the intrinsic parameters of propagule pressure: implications for bio-invasion. *Ecosphere, 3*, art48.

Herrera, V., (Chief Technical Officer) 2012. Permission Under Sections 52 and 53 of the Biosecurity Act 1993 (Notice No. MPI 111). *New Zealand Gazette, 148*, 4409.

Hewitt, C.L., Campbell, M.L., 1999. Vectors, shipping and trade. In C. L. Hewitt, M. L. Campbell, R. E. ThresherR. B. Martin (Eds.), *Marine Biological Invasions of Port Phillip Bay, Victoria. Centre for Research on Introduced Marine Pests. Technical Report No.20*. CSIRO Marine Research, Hobart. pp.45-60

Hewitt, C.L., Campbell, M.L., 2010. *The relative contribution of vectors to the introduction and translocation of marine invasive species*. A report prepared by the National Centre for Marine Conservation and Resource Sustainability within the Australian Maritime College for the Australian Department of Agriculture, Fisheries and Forestry (DAFF) Barton, ACT, Australia. 56 p.

Hewitt, C.L., Willing, J., Bauckham, A., Cassidy, A.M., Jones, L., Wooton, D.M., 2004. New Zealand marine biosecurity: delivering outcomes in a fluid environment. *New Zealand Journal of Marine and Freshwater Research, 38*, 429-438.

Hilliard, R., Polgaze, J., LeProvost, I., 2006. Review and evaluation of the biofouling protocol for vessels less than 25 m in length. A report prepared for the Australian Quarantine and Inspection Service, Canberra.

Hoagland, P., Beaulieu, S., Tivey, M.A., Eggert, R.G., German, C., Glowka, L., et al., 2010. Deep-sea mining of seafloor massive sulfides. *Marine Policy, 34*, 728-732.

Hodson, S.L., Lewis, T.E., Burke, C.M., 1997. Biofouling of fish-cage netting: Efficacy and problems of in situ cleaning. *Aquaculture, 152*, 77-90.

Holm, E.R., Haslbeck, E.G., Horinek, A.A., 2003. Evaluation of brushes for removal of fouling from fouling-release surfaces, using a hydraulic cleaning device. *Biofouling, 19*, 297-305.

Hopkins, G.A., Forrest, B.M., 2008. Management options for vessel hull fouling: an overview of risks posed by in-water cleaning. *ICES J. Mar. Sci., 65*, 811-815.

Hopkins, G.A., Forrest, B.M., 2010. Challenges associated with pre-border management of biofouling on oil rigs. *Marine Pollution Bulletin, 60*, 1924-1929.

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

ICES. 2005a. *The intentional introduction of the marine red king crab Paralithodes camtschaticus into the Southern Barents Sea.* ICES Cooperative Research Report No. 277. International Council for Exploration of the Sea, Denmark. 25 p.

ICES. 2005b. *Vector pathways and the spread of exotic species in the sea*. ICES Cooperative Research Report No. 271. International Council for Exploration of the Sea, Denmark. 18 p.

ICES 2005c. *Code of practice on the introductions and transfers of marine organisms*. Copenhagen, Denmark: ICES.

Inglis, G., Woods, C., Willis, K., Read, G., Seaward, K., 2008. *Incursion response to the Mediterranean Fanworm Sabella spallanzanii (Gmelin, 1791), in the Port of Lyttelton - Interim Measures.* NIWA Client Report No. CHC2008-141. Prepared for MAF Biosecurity New Zealand contract MAF09501. NIWA, Christchurch.

Inglis, G.J., Floerl, O., Ahyong, S., Cox, S., Unwin, M., Ponder-Sutton, A., et al., 2010. *The biosecurity risks associated with biofouling on international vessels arriving in New Zealand: Summary of the patterns and predictors of fouling.* Biosecurity New Zealand Technical Paper No: 2008/. A report prepared for MAF Biosecurity New Zealand Policy and Risk Directorate Project RFP0811321. 182 p.

Inglis, G.J., Floerl, O., Woods, C., 2012. *Scenarios of vessel biofouling risk and their management: an evaluation of options*. MAF Technical Paper No: 2012/07, Prepared for MAF Research Project RFP11832. Ministry for Agriculture and Forestry, Wellington. 122 p.

International Maritime Organization. 2012. *Guidance for minimizing the transfer of invasive aquatic species as biofouling (hull fouling) for recreational craft* (No. 7). International Maritime Organization, London. 7 p.

International Maritime Organization. 2013a. *List of ballast water management systems that make use of active substances which have received Basic Approval from the IMO.* <Retrieved 06/03/2013, 2013, from http://www.imo.org/OurWork/Environment/BallastWaterManagement/Documents/table%20updated%20in%20October%202012%20including%20TA%20information.pdf>

International Maritime Organization. 2013b. *Status of conventions*. <Retrieved 6/03/2013, from http://www.imo.org/About/Conventions/StatusOfConventions/Pages/Default.aspx >

International Seabed Authority. 2008. *Polymetalic nodules* <Retrieved 17 June 2013, 2013, from http://www.isa.org.jm/files/documents/EN/Brochures/ENG7.pdf>

IPIECA, International Association of Oil & Gas Producers. 2010. *Alien invasive species and the oil and gas industry - Guidance for prevention and management*. OGP Report Number 436. London, United Kingdom. 82 p.

IUCN. 2007. *Guide for the sustainable development of Mediterranean aquaculture. Interaction between aquaculture and the environment*. International Union for the Conservation of Nature, Gland, Switzerland and Malaga, Spain. 107 p.

Jensen, D.A., Lichtkoppler, F., Starinchak, J., Meyers, M., 2006. *Habattitude™ baseline survey shows that aquarists and water gardeners can be the problem and solution to AIS spread*. Paper presented at the Fourteenth International Conference on Aquatic Invasive Species. Key Biscayne, Florida, USA. 14-19 May 2006.

Johnson, L.E., Ricciardi, A., Carlton, J.T., 2001. Overland dispersal of aquatic invasive species: A risk assessment of transient recreational boating. *Ecological Applications, 11*, 1789-1799.

Johnson, L.T., Fernandez, L.M., 2011. A binational, supply-side evaluation for managing water quality and invasive fouling species on California's coastal boats. *Journal of Environmental Management, 92*, 3071-3081.

Johnson, L.T., Fernandez, L.M., Lande, M.D., 2012. *Crossing boundaries: managing invasive species and water quality risks for coastal boat hulls in California and Baja California* (UCCE-SD Technical Report No. 2012-1). University of California. 16 p.

Johnson, L.T., Gonzalez, J.A., 2008. *Alternative anti-fouling strategies sampler*. Produced for California Sea Grant College Program Report No. T-065 San Diego: University of California Cooperative Extension Sea Grant Extension Program. 12 p.

Johnstone, I.M., Coffey, B.T., Howard-Williams, C., 1985. The role of recreational boat traffic in interlake dispersal of macrophytes: a New Zealand case study. *Journal of Environmental Management, 20*, 263-279.

Keeley, N., Forrest, B., Hopkins, G., Gillespie, P., Clement, D., Webb, S., et al., 2009. *Review of the ecological effects of farming shellfish and other non-finfish species in New Zealand*. Cawthron Report No. 1476, prepared for the Ministry of Fisheries. Cawthron Institute, Nelson. 144 p.

Kikillus, K.H., Hare, K.M., Hartley, S., 2012. Online trading tools as a method of estimating propagule pressure via the pet-release pathway. *Biological Invasions, 14*, 2657-2664.

King, D.M., Hagan, P.T., Riggio, M., Wright, D.A., 2012. Preview of global ballast water treatment markets. *Journal of Marine Engineering and Technology, 11*, 3-15.

Knapp, A.K., Franses, P.H., 2006. Analysis of the Maritime Inspection Regimes – Are ships over-inspected?, *Econometric Institute Report 2006-30*. Econometric Institute, Erasmus University Rotterdam. 39 p.

Knight, E., Barry, S., Summerson, R., Cameron, S., Darbyshire, R., 2007. *Designated exchange areas project – providing informed decisions on the discharge of ballast water in Australia (Phase 2)*. Bureau of Rural Sciences,Canberra, ACT, Australia. 93 p.

Kollmuss, A., Agyeman, J., 2002. Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research, 8*, 239-260.

Kospartov, M., Inglis, G., Seaward, K., van den Brink, A., D'Archino, R., Ahyong, S., 2008. *Non-indigenous and cryptogenic marine species in New Zealand - Current state of knowledge: Interim report*. NIWA Research Report prepared for MAF-BNZ Project BNZ10740. 25 pp + tables + appendices.

Lacoursière-Roussel, A., Forrest, B.M., Guichard, F., Piola, R.F., McKindsey, C., 2012. Modeling biofouling from boat and source characteristics: a comparative study between Canada and New Zealand. *Biological Invasions 14*, 2301-2314.

Land Information New Zealand. 2012. Shipping routes around the New Zealand coast. *New Zealand Nautical Almanac 2012 – 13*. Land Information New Zealand, Wellington. pp. 239-244

Lavoie, D.M., Smith, L.D., Ruiz, G.M., 1999. The potential for intracoastal transfer of non-indigenous species in the ballast water of ships. *Estuarine, Coastal and Shelf Science, 48*, 551-564.

le Blanc, N., Davidson, J., Tremblay, R., McNiven, M., Landry, T., 2007. The effect of anti-fouling treatment for the clubbed tunicate on the blue mussel, *Mytilus edulis*. *Aquaculture 264*, 205-213.

LeBlanc, N., Davidson, J., Tremblay, R., McNiven, M., Landry, T., 2007. The effect of anti-fouling treatments for the clubbed tunicate on the blue mussel, *Mytilus edulis*. *Aquaculture, 264*, 205-213.

Lewbel, G.S., Howard, R.L., Gallaway, B.J., 1987. Zonation of dominant fouling organisms on northern gulf of Mexico petroleum platforms. *Marine Environmental Research, 21*, 199-224.

Lewis, J.A., Dimas, J.A., 2007. *Treatment of biofouling in internal seawater systems - phase 2*. Maritime Platforms division, Defence Science and Technology Organisation, Victoria, Australia. 32 p.

Lleonart, M., Handlinger, J., Powell, M., 2003. Spionid mudworm infestation of farmed abalone (*Haliotis* spp.). *Aquaculture, 221*, 85-96.

Locke, A., Doe, K.G., Fairchild, W.L., Jackman, P.M., Reese, E.J., 2009. Preliminary evaluation of effects on invasive tunicate management with acetic acid and calcium hydroxide on non-target marine organisms in Prince Edward Island, Canada. *Aquatic Invasions, 4*, 221-236.

Locke, A., Hanson, J.M., Ellis, K.M., Thompson, J., Rochette, R., 2007. Invasion of the southern Gulf of St. Lawrence by the clubbed tunicate (*Styela clava* Herdman): Potential mechanisms for invasions of Prince Edward Island estuaries. *Journal of Experimental Marine Biology and Ecology, 342*, 69-77.

Lutz-Collins, V., Ramsay, A., Quijon, P.A., Davidson, J., 2009. Invasive tunicates fouling mussel lines: evidence of their impact on native tunicates and other epifaunal invertebrates. *Aquatic Invasions, 4*, 213-220.

Lützen, J., 1999. *Styela clava* Herdman (Urochordata, Ascidiacea), a successful immigrant to north west Europe: ecology, propagation and chronology of spread. *Helgolander Meeresuntersuchungen, 52*, 383-391.

Lyons, B.S.B., 2007. In the dry-dock: an inside look at the orchestrated chaos when a ship leaves service for servicing. *Cruise Travel Magazine, September/October 2007*, 38-41.

Lyttelton Port Company. 2012. *Capital and Maintenance Dredging Consents Project*. Fact Sheet Lyttelton Port Company, Christchurch. 3 p.

MacDiarmid, A., Beaumont, J., Bostock, H., Bowden, D., Clark, M., Hadfield, M., et al., 2012. *Expert risk assessment of activities in the New Zealand Exclusive Economic Zone and Extended Continental Shelf*. NIWA Client Report No: WLG2011-39, prepared for the Ministry for the Environment. NIWA, Wellington. 138 p.

Mackenzie, L., Beauchamp, T., 2001. *Gymnodinium catenatum in New Zealand: a new problem for public health and the shellfish industry*. Cawthron Report, Cawthron Research Institute, Nelson, New Zealand. 10 p.

MacLeod, C., Eriksen, R., 2009. *A review of the ecological impacts of selected antibiotics and antifoulants currently used in the Tasmanian salmonid farming industry (Marine Farming Phase).* FRDC Final Report (Project No. 2007/246): Fisheries Research and Development Corporation, Deakin, ACT, Australia. 154 p.

MAF Biosecurity New Zealand. 2007a. *Clean Boats - Living Seas, A boatie's guide to marine biosecurity.* MAF Biosecurity New Zealand, Wellington. 32 p.

MAF Biosecurity New Zealand. 2007b. *Managing and controlling the risk to the marine environment from ballast water discharges - New Zealand's response to the International Convention for the Control and Management of Ships' Ballast Water & Sediments*. MAF Biosecurity New Zealand Discussion Paper No: 2007/04. MAF Biosecurity New Zealand, Wellington. 30 p.

MAF Biosecurity New Zealand. 2011. *Draft anti-fouling and in-water cleaning guidelines*. MAF Discussion Paper No: 2011/13. Ministry of Agriculture and Forestry, Wellington. 42 p.

Mahle Industrial Filtration. 2008. *Bilge water separation - reliable, powerful, economical*. Mahle Industrial Filtration, Hamburg, Germany. 20 p.

Maritime New Zealand. 2008. *Boating safety strategy, 2007: review of the New Zealand pleasure boat safety strategy*. Maritime New Zealand, Wellington. 92 p.

Maritime New Zealand. 2009. *Part 120: Discharge of oil*. Marine Protection Rules - MNZ Consolidation. Maritime New Zealand, Wellington. 21 p.

Maritime New Zealand. 2011a. *2011 Briefing to the Incoming Minister*. Maritime New Zealand, Wellington. 19 p.

Maritime New Zealand. 2011b. *A guide to fishing vessel stability*. Maritime New Zealand, Wellington. 32 p.

Maritime New Zealand. 2011c. *Part 21: Safe ship management systems*. Maritime Rules - MNZ Consolidation. Maritime New Zealand, Wellington. 21 p.

Maritime New Zealand. 2011d. *Part 46: Surveys, certification and maintenance*. Maritime Rules - MNZ Consolidation. Maritime New Zealand, Wellington. 18 p.

Maritime New Zealand. 2011e. *Part 122: Marine protection products - oil*. Marine Protection Rules - MNZ Consolidation. Maritime New Zealand, Wellington. 11 p.

Mazue, G., Viennet, R., Hihn, J.Y., Carpentier, L., Devidal, P., Albaïna, I., 2011. Large-scale ultra-sonic cleaning system: Design of a multi-transducer device for boat cleaning (20 kHz). *Ultra-sonics Sonochemistry, 18*, 895-900.

McClary, D.J., Nelligan, R.J., 2001. *Alternate biosecurity management tools for vector threats: technical guidelines for acceptable hull cleaning facilities.* A report prepared for Ministry of Fisheries project no. ZBS2000/03. Kingett Mitchell & Associates Ltd, Auckland. 29 p.

McCollin, T., Shanks, A.M., Dunn, J., 2007. The efficiency of regional ballast water exchange: Changes in phytoplankton abundance and diversity. *Harmful Algae, 6*, 531-546.

McDowall, R.M., 2004. Shoot first, and then ask questions: a look at aquarium fish imports and invasiveness in New Zealand. *New Zealand Journal of Marine and Freshwater Research, 38*, 503-510.

McKindsey, C.W., Landry, T., O'Beirn, F.X., Davies, I.N., 2007. Bivalve aquaculture and exotic species: A review of ecological considerations and management issues. *Journal of Shellfish Research, 26*, 281-294.

Meinesz, A., de Vaugelas, J., Hesse, B., Mari, X., 1993. Spread of the introduced tropical green alga *Caulerpa taxifolia* in northern Mediterranean waters. *Journal of Applied Phycology, 5*, 141-147.

Mincher, R., 2008. New Zealand's Challenger Scallop Enhancement Company: from reseeding to self-governance. *FAO fisheries technical paper, 504*, 307.

Minchin, D., 2007. Aquaculture and transport in a changing environment: Overlap and links in the spread of alien biota. *Marine Pollution Bulletin, 55*, 302-313.

Ministerial Inquiry Panel. 2012. *Report of the Ministerial Inquiry into the use and operation of Foreign Charter Vessels*. Ministry of Agriculture & Forestry, Wellington. 128 p.

Ministry for Primary Industries. 2012a, 16/10/2012. The New Zealand Fishing Industry. <Retrieved 15/06/2013, 2013, from http://www.fish.govt.nz/en-nz/Commercial/About+the+Fishing+Industry/default.htm>

Ministry for Primary Industries. 2012b. *Unwanted organism permission - application form*. Ministry for Primary Industries. Ministry for Primary Industries, Wellington. 6 p.

Ministry for Primary Industries. 2013. *Draft - Risk assessment policy and process for fishing vessels in New Zealand*. Ministry for Primary Industries, Wellington. 32

Ministry for the Environment, Ministry of Tourism. unknown. *Marine activities sustainability guide*. Developed for New Zealand marine-based tourism businesses by the Ministry for the Environment and Ministry of Tourism. Ministry for the Environment, Wellington. 4 p.

Ministry of Agriculture and Forestry. 2011, 8 September 2011. Standard for General Transitional Facilities for Uncleared Goods (TF Gen). <Retrieved 27 October 2011, 2011, from http://www.biosecurity.govt.nz/border/transitional-facilities/bnz-std-tfgen>

Ministry of Business Innovation and Employment. 2012. *Economic contribution and potential of New Zealand's oil and gas industry*. Economic Development Group Occasional Paper. Ministry of Business, Innovation and Employment, Wellington. 20 p.

Ministry of Fisheries. 2011a. *Draft national fisheries plan for deep-water and middle-depth fisheries*. Ministry of Fisheries. Wellington. 59 p.

Ministry of Fisheries. 2011b. *Draft national fisheries plan for highly migratory species (HMS)*. Ministry of Fisheries, Wellington. 53 p.

Ministry of Fisheries. 2011c. *Draft national fisheries plan for inshore finfish*. Ministry of Fisheries, Wellington. 61 p.

Ministry of Transport. 2008. *Sea change: transforming coastal shipping in New Zealand*. A strategy for domestic sea freight: May 2008. Ministry of Transport, Wellington. 40 p.

Morris, J.A., Jr., Carman, M.R., 2012. Fragment reattachment, reproductive status, and health indicators of the invasive colonial tunicate *Didemnum vexillum* with implications for dispersal. *Biological Invasions, 14*, 2133-2140.

Morrisey, D., Bradley, A., Fitridge, I., Inglis, G., Neil, K., 2007. *Assessment of arrangements for managing marine pest risks in the aquarium trade*. NIWA client report no. NEL2007-015, prepared for Australian Dept of Agriculture, Fisheries and Forestry project DAFF01/2007. NIWA, Nelson. 163 p.

Morrisey, D., Gadd, J., Page, M., Floerl, O., Woods, C., Lewis, J., et al., 2013. *In-water cleaning of vessels - biosecurity and chemical contamination risks*. MPI Technical Paper No: 2013/11. Ministry for Primary Industries, Wellington. 265 p.

Morrisey, D., Inglis, G., Neil, K., Bradley, A., Fitridge, I., 2011. Characterization of the marine aquarium trade and management of associated marine pests in Australia, a country with stringent import biosecurity regulation. *Environmental Conservation, 38*, 89-100.

Morrisey, D., Page, M., Handley, S., Middleton, C., Schick, R., 2009. *Biology and ecology of the introduced ascidian Eudistoma elongatum, and trials of potential methods for its control*. MAF Biosecurity New Zealand Technical Paper No. 2009/21. MAF Biosecurity New Zealand, Wellington. 63 p.

Morrisey, D., Page, M., Seaward, K., Boustead, N., 2010. *Aquatic Animal Pest and Disease Readiness Planning and Intelligence. Phase I – Data Acquisition (2009 – 11481)*. MAF Biosecurity New Zealand Technical Paper No: 2010/16.

Morrisey, D.J., 2003. *Assessment of ecological effects of beach renourishment of Tahunanui Beach, Nelson*. NIWA client report no. NEL2004-001, prepared for Staig & Smith Ltd. NIWA, Nelson. 17 p.

Murray, A.G., Smith, R.J., Stagg, R.M., 2002. Shipping and the spread of infectious salmon anemia in Scottish aquaculture. *Emerging Infectious Diseases, 8*, 1-5.

Nel, R., Coetzee, P.S., Vanniekerk, G., 1996. The evaluation of two treatments to reduce mud worm (*Polydora hoplura* Claparède) infestation in commercially reared oysters (*Crassostrea gigas* Thundberg). *Aquaculture, 141*, 31-39.

New Zealand Government. 2012. *Business growth agenda progress reports - building natural resources*. New Zealand Government, Wellington. 36 p.

New Zealand King Salmon. 2011. *Anti-fouling report*. Assessment of Environmental Effects Appendices New Zealand King Salmon Ltd, Nelson. 8 p.

New Zealand Marina Operators Association. 2008. *Tips for boaties on protecting our marine environment*. New Zealand's Clean Boating Programme. New Zealand Marina Operators Association, 20 p.

New Zealand Petroleum & Minerals. 2011. *Mineral estate - fact sheet*. New Zealand Petroleum & Minerals, Ministry of Business, Innovation and Employment, Wellington. 4 p.

New Zealand Petroleum & Minerals. 2013. *New Zealand petroleum basins*. New Zealand Petroleum & Minerals, Ministry of Business, Innovation and Employment, Wellington. 36 p.

New Zealand Salmon Farmers Association, 2007. *Finfish aquaculture environmental code of practice.* New Zealand Salmon Farmers Association, Inc., Nelson. 27 p.

Northern Territory Government. 2013, 13/04/2012. *Marine pest inspections*. <Retrieved 15/06/2013, 2013, from http://www.nt.gov.au/d/Fisheries/index.cfm?newscat1=&newscat2=&header=Vessel%20Inspections>

Northland Regional Council. 2012. *Mooring guidelines - Edition 1, 2012*. Northland Regional Council, Whangarei. 34 p.

Notteboom, T.E., 2006. The time factor in liner shipping services. *Maritime Economics & Logistics, 8*, 19-39.

Office of the Minister for Biosecurity. 2010. *Revised policy governing the commercial use of Undaria — an exotic Asian seaweed*. MAF ref: Sub 09-52, Cabinet ref: CAB Min (10) 13/1. Ministry for Agriculture and Forestry, Wellington. 10 p.

Padilla, D.K., Williams, S.L., 2004. Beyond ballast water: aquarium and ornamental trades as sources of invasive species in aquatic ecosystems. *Frontiers in Ecology and the Environment, 2*, 131-138.

Paetzold, S.C., Davidson, J., 2011. Aquaculture fouling: efficacy of potassium monopersulphonate triple salt based disinfectant (Virkon® Aquatic) against *Ciona intestinalis*. *Biofouling, 27*, 655-665.

Paetzold, S.C., Davidson, J., Giberson, D., 2008. Responses of *Mitrella lunata* and *Caprella* spp., potential tunicate micropredators, in Prince Edward Island estuaries to acetic acid anti-fouling treatments. *Aquaculture, 285*, 96-101.

Piola, R., Dunmore, R., Forrest, B., 2008. *Evaluation of marine response tools: spray treatments.* MAF Biosecurity New Zealand Technical Paper No: 2010/23. MAF Biosecurity New Zealand, Wellington. 177 p.

Piola, R., Dunmore, R., Forrest, B.M., 2010. Assessing the efficacy of spray-delivered “eco-friendly” chemicals for the control and eradication of marine fouling pests. *Biofouling, 26*, 187-203.

Piola, R., Forrest, B., 2009. *Options for managing biosecurity risks from recreational vessel hubs*. Cawthron report no. 1591, prepared for Nelson City Council. Cawthron Institute, Nelson. 45 p.

Piola, R.F., Conwell, C., 2010. *Vessel biofouling as a vector for the introduction of non-indigenous marine species to New Zealand: fishing vessels.* MAF Biosecurity New Zealand Technical Paper No: 2010/11, MAF Biosecurity New Zealand, Wellington. 57 p.

Piola, R.F., Hopkins, G.A., 2012. Thermal treatment as a method to control transfers of invasive biofouling species via vessel sea-chests. *Marine Pollution Bulletin, 64*, 1620-1630.

Polonsky, M.J., Binney, W., Hall, J., 2004. Developing better public policy to motivate responsible environmental behavior – an examination of managers' attitudes and perceptions towards controlling introduced species. *Journal of Nonprofit & Public Sector Marketing, 12*, 93-107.

Pool, T.K., Luis, S., Olden, J.D., 2013. Assessing lethal dissolved oxygen tolerance for invasive tunicate *Ciona savignyi* in Puget Sound. *Northwest Science, 87*, 106-113.

Poole, A., 2011. Advanced materials and surface technologies for reducing biofouling. <Retrieved 11 April 2011, 2013, from http://www.csiro.au/en/Outcomes/Oceans/Marine-Life/Reducing-Marine-Biofouling.aspx>

Preece, P.A., Shepherd, S.A., Clarke, S.M., Keesing, J.K., 2000. *Feasibility of enhancing abalone stocks by larval seeding*. Project number 94/005. South Australian Research and Development Institute, Adelaide. 49 p.

Pricewaterhouse Coopers. 2011. *Proposed Australian biofouling management requirements - consultation Regulation Impact Statement*. A report prepared for the Commonwealth Department of Agriculture, Fisheries and Forestry, Canberra, Australia. 82 p.

Pullar, A., Hughes, S., 2009. *Project next generation - dredging methodology and disposal alternatives*. A report prepared for Port Otago Ltd Dunedin: Port Otago Ltd & Stuart Hughes Associates Ltd, Dunedin. 53 p.

Reaser, J.K., 2001. Invasive alien species prevention and control: the art and science of managing people. In J. A. McNeely (Ed.), *The Great Re-shuffling: Human Dimension of Invasive Alien Species* (pp. 89-104). Gland, Switzerland: IUCN - World Conservation Union.

Roberts, R.D., 2013. SpatNZ. *Seafood New Zealand, April*, 13-14.

Robinson, J., 2011. Ocean's Treasure. *Water & Atmosphere, February 2011*(2), 10-19.

Rockpoint Corporate Finance Ltd. 2009. *Coastal shipping and modal freight choice*. A report prepared for the New Zealand Transport Agency for the 2008/09 Domestic Sea Freight Development Fund (DSFDF). New Zealand Transport Agency, Wellington. 124 p.

Rothlisberger, J.D., Chadderton, W.L., McNulty, J., Lodge, D.M., 2010. Aquatic invasive species transport via trailered boats: what is being moved, who is moving it, and what can be done? *Fisheries, 35*, 121-132.

Ruiz, G., Carlton, J., 2003. *Invasive species - vectors and management strategies*. Washington, DC: Island Press.

Ruiz, G.M., Reid, D.F., 2007. *Current state of understanding about the effectiveness of ballast water exchange (BWE) in reducing aquatic non-indigenous species (ANS) introductions to the Great Lakes Basin and Chesapeake Bay, USA: synthesis and analysis of existing information*. NOAA Technical Memorandum GLERL-142. NOAA, Ann Arbor, Michigan. 127 p.

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

Scardino, A.J., de Nys, R., 2011. Mini review: Biomimetic models and bioinspired surfaces for fouling control. *Biofouling, 27*, 73-86.

Schaffelke, B., Deane, D., 2005. Desiccation tolerance of the introduced marine green alga *Codium fragile* ssp *tomentosoides* - clues for likely transport vectors? *Biological Invasions, 7*, 557-565.

Schoute, E., 2013. *Phosphate mining on the Chatham Rise*. Paper presented at the EMSAGG Seminar on Opportunities for European Mineral Resources. 26/02/2013, Bundesamt fur Seeschiffart und Hydrographie (BSH), Hamburg. Boskalis Offshore. 40 p.

Semmens, B.X., Buhle, E.R., Salomon, A.K., Pattengill-Semmens, C.V., 2004. A hotspot of non-native marine fishes: evidence for the aquarium trade as an invasion pathway. *Marine Ecology Progress Series, 266*, 239-244.

Seth, N., Chakravarty, P., Khandeparker, L., Anil, A.C., Pandit, A.B., 2010. Quantification of the energy required for the destruction of *Balanus amphitrite* larva by ultra-sonic treatment. *Journal of the Marine Biological Association of the United Kingdom, 90*, 1475-1482.

Sinner, J., Forrest, B., Newton, M., Hopkins, G., Inglis, G., Woods, C., Morrisey, D. (2013) *Managing the domestic spread of harmful marine organisms: Part B. Statutory framework and analysis of options*. Cawthron report no. 2442, Prepared for Ministry for Primary Industries project RFP15830. Cawthron Institute, Nelson. 73 p.

Sinner, J., Forrest, B.M., Piola, R.F., Roberts, B., 2009. *Fiordland marine biosecurity risk management: operational plan recommendations 2009-2013.* Cawthron Report 1621, Prepared for MAF Biosecurity New Zealand and Fiordland Marine Guardians. Cawthron Institute, Nelson. 32 p.

Slabbekoorn, H., Bouton, N., van Opzeeland, I., Coers, A., ten Cate, C., Popper, A.N., 2010. A noisy spring: the impact of globally rising underwater sound levels on fish. *Trends in Ecology & Evolution, 25*, 419-427.

Sliskovic, M., Jelic-Mrcelic, G., Antolic, B., Anicic, I., 2011. The fouling of fish farm cage nets as bioindicator of aquaculture pollution in the Adriatic Sea (Croatia). *Environmental Monitoring and Assessment, 173*, 519-532.

Smith, K.F., Acosta, H., Broom, J.E., Rhodes, L.L., 2010. Identification of non-indigenous marine macroalgae from New Zealand aquaria outlets. *New Zealand Journal of Marine and Freshwater Research, 44*, 29-37.

Sport and Recreation New Zealand. 2009. *Sport and recreation participation levels: findings from the 2007/08 Active NZ Survey.* Sport and Recreation New Zealand, Wellington. 7 p.

Stachowitsch, M., Kikinger, R., Herler, J., Zolda, P., Geutebrück, E., 2002. Offshore oil platforms and fouling communities in the southern Arabian Gulf (Abu Dhabi). *Marine Pollution Bulletin, 44*, 853-860.

Stebbing, P., Sebire, M., Lyons, B., 2011. *Evaluation of a number of treatments to be used as biosecurity measures in controlling the spread of the invasive killer shrimp (Dikerogammarus villosus) – Final Report (September 2011)*. CEFAS contract report C5256. Centre for Environment, Fisheries & Aquaculture Science, Suffolk, United Kingdom. 39 p.

Takata, L., Falkner, M., Gilmore, S., 2006. *Commercial vessel fouling in California. Analysis, evaluation, and recommendations to reduce non-indigenous species release from the non-ballast water vector*). California State Lands Commission, Marine Facilities Division. 76 p.

Tan, C.K.F., Nowak, B.F., Hodson, S.L., 2002. Biofouling as a reservoir of *Neoparamoeba pemaquidensis* (Page, 1970), the causative agent of amoebic gill disease in Atlantic salmon. *Aquaculture, 210*, 49-58.

Thompson Clarke Shipping Pty Ltd, CTI Consultants Pty Ltd, Lewis, J.A., 2007. *Anti-fouling performance standards for the maritime industry: Development of a framework for the assessment, approval and relevance of effective products*. A report prepared for the Australian Natural Heritage Trust Canberra, Australia. 61 p.

Thompson, G.A. 2004. *Mechanisms of invasion and persistence of the invasive kelp Undaria pinnatifida (Harvey) Suringar within intertidal areas of southern New Zealand.*, Doctoral Thesis, University of Canterbury, Christchurch.

Torchin, M.E., Lafferty, K.D., Kuris, A.M., 2002. Parasites and marine invasions. *Parasitology, 125*, 576-576.

Tourism New Zealand. 2007. *2006/07 Cruise research: understanding the New Zealand cruise experience*. Tourism New Zealand, Wellington. 22 p.

Trowbridge, C.D., 1998. Ecology of the green macroalga *Codium fragile* (Suringar) Hariot 1889: invasive and non-invasive subspecies. *Oceanography and Marine Biology: An Annual Review, 36*, 1-64.

U.S. Army Corps of Engineers. 1987. Underwater cleaning of concrete and steel: High-pressure water jets, *REMR Technical Note CS-ES-3.5*. Repair-evaluation-Maintenance-Rehabilitation Research Programme. U.S. Army Corps of Engineers, Washington D.C. 4 p.

UMR Research Ltd. 2006. *Marine market research: a quantitative study*. A report prepared for MAF Biosecurity New Zealand. UMR Research, Wellington. 81 p.

Victorian Abalone Divers Association. 2007. *SOP 2: Protocol for decontamination of vessels, personnel, machinery and equipment*. Bio-Security Control Measures for Abalone Herpes Like Virus: A Code of Practise. Victorian Abalone Divers Association, Melbourne, Australia. 6 p.

Vucko, M.J., King, P.C., Poole, A.J., Carl, C., Jahedi, M.Z., de Nys, R., 2012. Cold spray metal embedment: an innovative anti-fouling technology. *Biofouling, 28*, 239-248.

Waikato Regional Council. 2012. *Resource use fact sheet series: moorings*. Waikato Regional Council, Hamilton: 6p.

Weigle, S.M., Smith, L.D., Carlton, J.T., Pederson, J., 2005. Assessing the risk of introducing exotic species via the live marine species trade. *Conservation Biology, 19*, 213-223.

West, E.J., Barnes, P.B., Wright, J.T., Davis, A.R., 2007. Anchors aweigh: fragment generation of invasive *Caulerpa taxifolia* by boat anchors and its resistance to desiccation. *Aquatic Botany, 87*, 196-202.

Whitfield, P.E., Gardner, T., Vives, S.P., Gilligan, M.R., Courtenay, J., W.R., Ray, G.C., et al., 2002. Biological invasions of the Indo-Pacific lionfish *Pterois volitans* along the Atlantic coast of North America. *Marine Ecology Progress Series, 235*, 289-297.

Willis, K.J., Woods, C.M.C., 2011. Managing invasive *Styela clava* populations: Inhibiting larval recruitment with medetomidine. *Aquatic Invasions, 6*, 511-514.

Wonham, M., Byers, J., Grosholz, E.D., Leung, B., 2013. Modeling the relationship between propagule pressure and invasion risk to inform policy and management. *Ecological Applications, 23,*1691–1706. http://dx.doi.org/10.1890/12-1985.1

Woods, C., Floerl, O., Fitridge, I., Johnston, O., Robinson, K., Rupp, D., et al., 2007. *Efficacy of hull cleaning operations in containing biological material. II. Seasonal variability*. MAF Biosecurity New Zealand Technical Paper No. 08/11. MAF Biosecurity New Zealand, Wellington. 116 p.

Woods, C.M.C., Floerl, O., Hayden, B.J., 2012. Biofouling on Greenshell™ mussel (*Perna canaliculus*) farms: a preliminary assessment and potential implications for sustainable aquaculture practices. *Aquaculture International, 20*, 537-557.

Wotton, D.M., O'Brien, C., Stuart, M., Fergus, D.J., 2004. Eradication success down under: heat treatment of a sunken trawler to kill the invasive seaweed *Undaria pinnatifida*. *Marine Pollution Bulletin, 49*, 844-849.

Wright, I., 2007, 30/01/2007. '*Marine minerals*'. Te Ara - the Encyclopedia of New Zealand. Retrieved 28/02/2007 http://www.TeAra.govt.nz/EarthSeaAndSky/MineralResources/MarineMinerals/en

Yeo, D.C.J., Ahyong, S.T., Lodge, D.M., Ng, P.K.L., Naruse, T., Lane, D.J.W., 2009. Semisubmersible oil platforms: understudied and potentially major vectors of biofouling-mediated invasions. *Biofouling, 26*, 179-186.

Zaleski, S.F., Murray, S.N., 2006. Taxonomic diversity and geographic distributions of aquarium-traded species of *Caulerpa* (Chlorophyta: Caulerpaceae) in southern California, USA. *Marine Ecology Progress Series, 314*, 97-108.

Appendix 1 Boatyards and vessel cleaning facilities in New Zealand. (Source: Inglis et al., 2012).

Location	Facility name	Capacity of hardstand	Lifting method	Max weight (t)	Max length (m)	Max. Beam (m)
Opua	Ashby's Boatyard	55 + undercover boat storage units	Travelift	50	21.3	5.2
	Ashby's Boatyard		Slipway	100	25	9.7
	Doug's Boatyard	Limited	Slipway	no data	no data	
Russell	Russell Marine Slipway Rails	2	Slipway	150	24	
Tutukaka	Tutukaka Marina	no data	Slipway	40	20	
Whangarei	Norsand Ltd	70	Slipway	70		11
	Dockland 5 Services	60	Travelift	70	no data	
	New Zealand Yachts International	no data	Slipway	800	60	20
	Riverside DriveMarina	30	Travelift	40	no data	
	Ship Repair NZ Ltd	no data	Slipway	40	no data	
	International Yacht Services Ltd	no data	no data	no data	no data	
	H&H Marine & Engineering Services	no data	Slipways x 2	70	no data	
Warkworth	Sandspit Yacht Club	no data	Slipway	10	12.5	
	Lees Boatbuilders	no data	Slipways x 2	no data	no data	
	Mahurangi Marina	no data	Stroplift	23	no data	
	Robertson Boats Ltd	5,000 m² hardstand + 3 sheds	Travelift	80		8.5
GulfHarbour	GulfHarbourMarina	15,000 m² hardstand + 800m² shed	Travelift x 2	110	30	7.9
Auckland	HalfmoonBayMarina (Auckland Maritime Foundation)	100	Travelift	35	18.29	
	Babcock Fitzroy Ltd / HMNZ Naval Base	4	Syncrolift	200	34	8.5
	Babcock Fitzroy Ltd / HMNZ Naval Base	no data	Slipway	100	no data	
	Westpark Marina	"extensive hardstand area"	Travelift	35	15.24	
	Westpark Marina		Travelift	75	24.39	
	Devonport Yacht Club	hardstand (capacity or area not specified)	Slipway	10		
	PineHarbourMarina	no data	Travelift	50	28	
	Orams Marine (Westhaven)	6,000m² hardstand	Travelift	60	25	6

Location	Facility name	Capacity of hardstand	Lifting method	Max weight (t)	Max length (m)	Max. Beam (m)
	Orams Marine (Westhaven)	sheds (4 vessels), temporary covered facility (1 vessel)	Slipway	600	55	
	Orams Marine (Westhaven)	310 vessels	Boat dry stack	no data	12	
	Pier 21 (Westhaven)	190 vessels	Boat dry stack	no data	9.2	
	Pier 21 (Westhaven)	30 vessels	Travelift	50	25	
	Floating Dock Services (Westhaven)	1	Floating dock	20	15	
	Titan Marine Engineering Ltd (Westhaven)	1?	Slipway	1500	80	
	ViaductHarbourMarineVillage	"unrestricted open-air hardstand and covered hardstand for vessels up to 10 metres high"	Travelift	35		5.8
	McMullen Wing & Wing Ltd	9290 m2 enclosed work space + "extensive outdoor storage space" + shed for 50m vessel	Travelift	70		6.8
	McMullen Wing & Wing Ltd		Slipway	300	50	
	Salthouse Boatbuilders	2 large sheds for vessels up to 30m	Slipways x 3	up to 80	30	
Tauranga	Refit NZ Ltd	12 vessels	Slipway	600	65	
	TaurangaBridgeMarina	no data	Travelift	35	20	
	Tauranga Marina Society	50 vessels	Travelift	35	20	
	Hutcheson Boatbuilders Ltd	20 vessels	Slipway	90	25	
Coromandel	Whitianga Marina	15 vessels	Travelift	35	no data	
Gisborne	Eastport Marina	no data	Travelift	No data	no data	
	Port Gisborne	no data	Slipway	400		35
Napier	Napier Sailing Club		Slipways x 3	20	12	
	Charter Boats Ltd	3 vessels	Slipways x 3	100 10	30 12	
	Napier Slip Way Ltd	no data	Slipways x 2	100 15	no data	
Wanganui	Q-West Boatbuilders	3 worksheds	Slipway	200	no data	
Taranaki	Port Taranaki	no data	Synchrolift	150	no data	
	Fitzroy Yachts	no data	Slipway	no data	no data	
Wellington	Seaview Marina	35 vessels	Travelift	50	20m	
	Chaffers Marina	None	Travelift	40	18	5.9
	ClydeQuayBoatHarbour / Royal Nicholson Yacht Club	no data	Slipway	no data	no data	

Location	Facility name	Capacity of hardstand	Lifting method	Max weight (t)	Max length (m)	Max. Beam (m)
	EvansBayMarina	no data	Slipway	18	14	
KapitiCoast	Mana Marina	no data	Travelift	30	20	
Havelock	Havelock Slipway	5 vessels	Slipways x 3	100	no data	
Picton	Carey's Boatyard	2 vessels	Slipways x 2	120	no data	
	Waikawa Marina (Franklin Boatyard)	3,555 m2 hardstand + 2 refit sheds	Travelift	35		5.2
Nelson	Dickson Marine (Refits) Ltd	1672m² hardstand	Travelift	50	24.4	6
	Calwell Slipway / Nelson Ship Repair Group	not specified	Slipways x 2	1800 100	65 30	
Lyttelton	Lyttelton Port Company	1 or 2	Dry-dock	600	120	
	Lyttelton Port Company	no data	Slipway	130	30	
	Stark Bros.	1	Slipway	30	20	
	Naval Point Yacht Club	23 cradles	Ramp + tractor	15		2.2 (draft)
Christchurch	Christchurch Yacht Club	no data	Slipways x 3	20	15	
Greymouth	Port of Greymouth	no data	Slipway	150		17 (keel length)
Timaru	Port of Timaru	no data	Slipway	45	15	4.5
Dunedin	Port Otago (Kitchener / Birch St Slipway)	no data	Slipway	500		
	Otago Yacht Club	hardstand (capacity not specified)	Slipway	12	12	
	Miller and Tunnage Boat Builders	4	Slipways x 4	100	30	
Dunedin	OtagoHarbour Recreational Boating Club	no data	Ramp	20	10	
Bluff	Southport NZ Ltd	12	Syncrolift	1050	45	
	OceanBeach Slip	4	Slipway	30	18	

Appendix 2. Mean, minimum and maximum charges for haul-out, wash and storage of vessels of different sizes (Source: Inglis et al. 2012).† All data are in New Zealand dollars.

Vessel Length		Haul-out and return to water ($)			Hardstand storage ($ - daily rate)			Waterblast clean ($)		
Feet	Metres	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
30.0	9.1	154.60	101.00	221.00	25.88	19.00	30.67	64.10	59.68	69.75
40.0	12.2	227.75	152.00	307.00	33.20	22.50	38.48	81.71	78.75	84.48
50.0	15.2	319.94	196.00	452.00	49.87	39.38	60.52	98.35	93.00	105.54
60.0	18.3	528.81	247.00	837.00	75.89	56.25	98.05	133.09	119.00	146.18
65.0	19.8	785.83	442.00	1074.00	96.00	73.13	121.80	176.62	158.40	185.82
72.0	22.0	999.25	532.00	1332.00	117.21	90.00	148.90	259.27	178.99	314.18

†Based on published 2010 rates from a sample of four boatyards from north-eastern New Zealand

Appendix 3 Range of recommended dosages and applications for different types of disinfectants in Scottish finfish aquaculture (Source: The Code of Good Practice for Scottish Finfish Aquaculture, http://www.thecodeofgoodpractice.co.uk/).

Disinfectant	Example*	Dose	Application
Sodium hypochlorite	Klorsept (Jencons Scientific, UK)	100 ppm, 10 min 1,000 ppm, 10 min 1,000 ppm, 6 h	Boats, cages, tanks, hand nets, harvest equipment Processing plant effluent Cage nets
Chloramine T	Halamid® (Axcentive, France)	1% (w/v), 5 min	Foot bath, non-porous surfaces
Chlorine dioxide	Zydox AD-05 activated by DRA-2 (Zychem Technologies, Norway)	100 ppm, 5 min	Processing plant effluent
Iodophor	Buffodine, FAM30 (Evans Vanodine, UK) or Tegodyne (DiverseyJohnson, UK)	100 ppm, 10 min	Foot bath, clothing, diving gear, hand nets, salmonid ova, non-porous surfaces
Peroxy compounds	Virkon S (Antec international, UK)	1% (w/v), 10 min (IPN) 0.5% (w/v), 30 min (ISA)	Foot baths, non-porous surfaces
Peracetic acid, hydrogen peroxide and acetic acid mix	Proxitane® 5 (Solvay Interox, UK)	0.4% (v/v), 5 min	Non-porous surfaces
Quarternary ammonium compounds	Cetrimide (FeF Chemicals A/S, Denmark)	125 ppm, 5 min	Plastic surfaces
Formic Acid		pH <4, 24 h	Ensiling fish waste
Ozone		8 mg/l/min, 3 min (Corresponding to redox potential 600-750 mV)	Water – intake and effluent
Heat		70°C, 2 h (IPN) 60°C, 2 min (ISA) 37°C, 4 days (Noda)	Cage nets, diving gear, steam cleaning non-porous surface
UV		122 mJ/cm^2/s (IPN) 290 mJ/cm^2/s (Noda)	Freshwater intake supply

Appendix 4. Summary of studies of effects of disinfectants on fouling organisms

Reference		Acetic acid	Hydrated lime	Bleach	Freshwater	Sodium hydroxide	Notes
MacNair & Smith 1998	Organism		*Molgula* sp.				
	Mortality		100% (after 10 d)				
	Concentration		4%				
	Duration of exposure		30 s				
Carver et al 2003	Organism	*Ciona intestinalis*	*Ciona intestinalis*	*Ciona intestinalis*	*Ciona intestinalis*		
	Mortality	100 (95)	70%	0%	10%		Spray or immersion equally effective
	Concentration	5%	4%	60ppm (0.12%)	NA		
	Duration of exposure	1 min (30 s)	8 min	20 min	1 min		
Williams & Schroder 2004	Organism			*Caulerpa taxifolia*			
	Mortality			100 (>90%)			
	Concentration			125ppm / 0.25% (50ppm / 0.10%)			
	Duration of exposure			30 min			
Coutts & Forrest 2005	Organism	*Styela clava*		*Styela clava*			
	Mortality	100%		100%			
	Concentration	4%		>200 mg/L			
	Duration of exposure	1 min		>12 h			
Forrest et al 2007	Organism	*Undaria pinnatifida*					
	Mortality						
	Concentration	<1% for gametophyte, <1% for plantlet, 4% for sporophyte					
	Duration of exposure	1 min					
Forrest et al 2007	Organism	Solitary and colonial ascidians, bryozoans					
	Mortality	100%					
	Concentration	2-4%					
	Duration of exposure	4 min					
Denny 2008	Organism	*Didemnum vexillum*	*Didemnum vexillum*	*Didemnum vexillum*	*Didemnum vexillum*	*Didemnum vexillum*	
	Mortality	100%	100%	100%	87%	100%	
	Concentration	4%	10%	250ppm / 0.5%	NA	6%	

Reference		Acetic acid	Hydrated lime	Bleach	Freshwater	Sodium hydroxide	Notes
	Duration of exposure	10 min	2 min	30 s	10 min	20 s	
Piola et al 2010	Organism	*Didemnum vexillum*					Some *Ciona intestinalis* individuals survived acetic acid treatment
	Mortality	100%					
	Concentration	5%					
	Duration of exposure	30 min					
	Organism	Several algal species					
	Mortality	ca 100%					
	Concentration	5%					
	Duration of exposure	1 min					
	Organism	Several invertebrate taxa	Number of invert. taxa				
	Mortality	55%	75-100% taxa				
	Concentration	5%	10-20%				
	Duration of exposure	1 min	>6 h				
	Organism	% cover of fouling		% cover of fouling			
	Mortality	65%		100%			
	Concentration	5%		20% bleach solution			
	Duration of exposure	1 min		30 min			