Scenarios of Vessel Biofouling Risk and their Management

An evaluation of options

MAF Technical Paper No: 2012/07

Prepared for MAF Research Project RFP11832
by Graeme Inglis, Oliver Floerl, Chris Woods (NIWA)

ISBN 978-0-478-38793-3(online)
ISSN 2230-2794 (online)

March 2012

Ministry of Agriculture and Forestry
Te Manatū Ahuwhenua, Ngāherehere

BIOSECURITY NEW ZEALAND

NEW ZEALAND FOOD SAFETY AUTHORITY

Disclaimer

While every effort has been made to ensure the information in this publication is accurate, the Ministry of Agriculture and Forestry (MAF) does not accept any responsibility or liability for error or fact omission, interpretation or opinion which may be present, nor for the consequences of any decisions based on this information. Any view or opinions expressed do not necessarily represent the official view of MAF.

The information in this report and any accompanying documentation is accurate to the best of the knowledge and belief of the National Institute of Water and Atmospheric Research (NIWA) acting on behalf of MAF. While NIWA has exercised all reasonable skill and care in preparation of information in this report, neither NIWA nor MAF accept any liability in contract, tort or otherwise for any loss, damage, injury, or expense, whether direct, indirect or consequential, arising out of the provision of information in this report.

Requests for further copies should be directed to:

Publication Adviser
MAF Information Bureau
P O Box 2526
WELLINGTON

Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the MAF website at
www.biosecurity.govt.nz/about-us/our-publications/technical-papers

Contents

Page

Executive Summary

The Ministry of Agriculture and Forestry New Zealand (MAF) is working toward implementation of an Import Health Standard (IHS) to address the biosecurity risks to New Zealand's marine environments associated with vessel biofouling. To facilitate implementation of the IHS, an understanding is needed of the range of options available to manage biofouling on non-compliant vessels and the risks that are associated with their application. Decisions about risk mitigation must balance biosecurity needs with those of New Zealand's other environmental, economic, social and cultural interests. The purpose of this project was to identify the consequences of different biofouling management options under various scenarios of non-compliance that may be encountered by MAF Border Inspectors. A range of scenarios of non-compliance was specified, based upon three primary factors:

- the type of non-compliant vessel (i.e. Recreational, Passenger, Fishing and Merchant vessels [including bulk carriers, tankers, container vessels, Ro/Ros, Reefers, etc]);
- the amount of time it is expected to spend in port (< 24 hrs, 1-14 days, > 14 days); and
- the number of port calls that it is expected to make while in New Zealand waters (Single port, Multiple ports).

For each scenario, 11 options for managing biofouling were evaluated against four MAF decision criteria: (i) feasibility, (ii) resource requirements, (iii) opportunities/barriers and (iv) strategic fit. The 11 management options considered in the study were:

- no action;
- education of vessel master through the use of communications materials;
- in-water treatment of biofouling by: (i) hand, (ii) mechanical tools, (iii) encapsulation, (iv) heat-treatment or (v) immersion in freshwater;
- haul out and cleaning by: (i) scraping, (ii) water-blasting, or (iii) desiccation; and
- refusal of entry into New Zealand.

Recommendations are provided on the management options that give greatest net benefit for each scenario. A draft decision framework was developed to support the creation of Border Clearance Procedures for Quarantine Inspectors presented with the arrival of non-compliant vessels.

Definitions

Anti-fouling system: a coating, paint, surface treatment, surface, or device that is used on a vessel 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.

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

Biosecurity: the exclusion, eradication or effective management of risks posed by pests and diseases to the economy, environment and human health.

Classification Societies: non-governmental organisations that establish and apply technical standards for the design, construction, and survey of vessels and offshore structures.

Consequence: the adverse effects or harm as a result of entry and establishment of a hazard, which cause environmental, economic and/or socio-cultural values to be degraded in the short or long term.

Clean: a vessel on which there are no visible aquatic organisms on the hull, including niche areas, except as a slime layer.

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

Establishment: perpetuation into the foreseeable future of organisms within an area of entry.

Free On Board (FOB) value: represents the actual or estimated transaction prices of goods, including costs incurred in delivering them on board ships.

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

Hazard: any disease or organism that has the potential to produce adverse consequences.

Hull: The immersed surfaces of a vessel including appendages, pontoons, internal sea-water systems, niche areas; except ballast tanks.

Inspector: a person who is appointed as an inspector under section 103 of the Biosecurity Act (1993).

Internal waters - means:

- 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.

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

MAF: Ministry of Agriculture and Forestry New Zealand.

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).

Negligible: to be so small or insignificant as not to be worth considering.

New Zealand waters - means:

- the internal waters of New Zealand; and
- the territorial sea of 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 waterline, sea chests, bow thrusters, propeller shafts, inlet gratings, jack-up legs, moon pools, bollards, braces and dry-docking support strips.

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.

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).

Risk: the likelihood of the occurrence and the likely magnitude of the consequences of an adverse event.

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

International Convention for the Safety of Life at Sea (SOLAS), 1974: an international maritime convention to which New Zealand is a party, that specifies minimum standards for the construction, equipment and operation of ships, compatible with their safety.

Territorial Sea: For New Zealand this is the sea within 12 nautical miles of the seaward side of the baseline of the territorial sea (see section 3 of the Territorial Sea, Contiguous Zone and Exclusive Economic Zone Act, 1977 for definition of New Zealand baseline).

TEU: 'Twenty-foot equivalent unit'. TEU is a standard measure of container volume that is used to describe the size of container vessels. One twenty-foot container is equivalent to one TEU.

Transitional facility: any place approved as a transitional facility in accordance with section 39 of the Biosecurity Act (1993) for the purpose of inspection, storage, treatment, quarantine, holding or destruction of specified types of un-cleared goods; or part of a port declared to be a transitional facility in accordance with section 39.

United Nations Convention on Law of the Sea 1982 (UNCLOS): a comprehensive international regime for the law of the sea, covering such matters as territorial and navigational rights, and the legal status and management of resources within.

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).

List of Figures

Page

List of Tables

Page

1 Introduction

A key biosecurity outcome for New Zealand that MAF is responsible for is that:

Harmful organisms are prevented from crossing New Zealand's borders and establishing, with the assurance that trade and tourism are maintained (MAF Biosecurity New Zealand 2007).

The discharge of ballast water and carriage of biofouling by vessels are the two most important pathways in which harmful marine organisms enter New Zealand waters (Hewitt et al. 2004; Inglis et al. 2010; Bell et al. 2011). In 1998, the New Zealand Government introduced mandatory controls on ballast water discharge in the form of the *Import Health Standard for Ships' Ballast Water from All Countries* (updated in June 2005; Biosecurity New Zealand 2005). MAF is now working toward implementation of an Import Health Standard (IHS) to address the biosecurity risks associated with vessel biofouling (MAF Biosecurity New Zealand 2010c). A draft IHS for vessel biofouling was released for public consultation in May 2010 following completion of a draft risk analysis (Bell et al. 2011).

In its draft form, the IHS for vessel biofouling will require the hull of any vessel arriving into New Zealand waters to be "clean"[1]. Vessels found not to comply with the IHS will be directed to take specified action to mitigate risks associated with the biofouling (MAF Biosecurity New Zealand 2010c). These actions may include:

- direction to be decontaminated in a MAF approved Transitional Facility for Hull: Cleaning or by in-water cleaning by a specified method;
- prohibition to enter the territorial sea;
- direction to leave New Zealand's jurisdiction within a specified time; or
- direction to not visit certain areas in New Zealand (MAF Biosecurity New Zealand 2010a).

Policy instruments for managing biosecurity risks associated with vessel biofouling are also beginning to be developed by other nations and international bodies. In Australia, the Commonwealth Government is currently considering implementing biofouling management requirements for all international vessel arrivals and some State Governments (e.g. Western Australia, Victoria and Northern Territory) have already implemented inspection regimes for certain vessel types. MAF is working with the Australian Commonwealth Government on a joint Code of Practice for Antifouling and In-water Hull Cleaning and Maintenance that will be consistent with the requirements of the draft IHS for vessel biofouling.

MAF has also contributed to an international correspondence group that developed draft guidelines on "*International Measures for Minimizing the Transfer of Invasive Aquatic Species through Biofouling of Ships*" for consideration by the International Maritime Organisation (IMO). The IMO's Sub-Committee on Bulk Liquids and Gases (BLG) has agreed to the draft guidelines that were adopted by IMO in July 2011.

1.1 PROJECT AIMS

To facilitate implementation of the draft IHS, an understanding is needed of the range of options available to manage biofouling on non-compliant vessels and the risks that are associated with their application. Decisions about risk mitigation must balance the biosecurity

[1] "Clean" is defined as when there are no visible aquatic organisms on the hull, including in niche areas, except as a slime layer (see Definitions).

needs with those of New Zealand's other environmental, economic, social and cultural interests.

The goal of this project was to inform development of procedures for decision-making by MAF Border Inspectors faced with vessels that are not compliant with the proposed vessel biofouling IHS. Decisions about mitigation of vessel biofouling should eliminate or significantly reduce the biosecurity risk while minimising the impact of the IHS on vessel operations and other core values.

The specific purpose of the project was to:

- identify the consequences of different biofouling management options under various scenarios of non-compliance with the IHS for vessel biofouling.

2 Summary of Methods

MAF specified a range of potential biofouling management options for consideration (Table 1) and the scenarios against which they were to be evaluated (Table 2). A more detailed description and review of the management options is provided in Section 4.

The efficacy and feasibility of each management option will vary depending upon the size and type of vessel, its place of arrival, and the time that it is available for treatment. The scenarios described in Table 2 are intended to encompass the range of situations that MAF Border Inspectors may encounter non-compliant vessels. The scenarios involve combinations of three factors:

- the type of vessel;
- the amount of time it is expected to spend in port ("turn-around time"); and
- the number of port calls that it will make while in New Zealand waters (Table 2).

Not all of the 54 combinations of the factors specified in Table 1 and Table 2 are likely to occur in New Zealand and some scenarios will occur infrequently. Similarly, some of the management options are unsuitable for particular types of vessels or are not available in New Zealand.

To determine how likely each scenario is we first described the physical characteristics, patterns of operation in New Zealand and drivers (both economic and social) of voyage schedules and hull husbandry for each type of vessel (Section 3). Information needed to evaluate each management option was obtained from a combination of literature review, analysis of existing data sets on international vessel visits to New Zealand and interviews with relevant stakeholders and technical specialists. Section 4 describes the management options in more detail and reviews their application to each vessel type relative to the MAF decision framework described below. Finally, in Section 5, we provide an assessment of recommended options for biofouling management for each scenario and vessel type based on the evaluation in Section 4.

Table 1: Biofouling management options considered in this project. These options are described in more detail in Section 4.

Management Options
1. No action taken
2. Education of vessel master through the use of communications materials
3. In-water cleaning (using appropriate technology to capture all debris) or treatment
3.1 Removal by hand
3.2 Mechanical removal
3.3 Encapsulation
3.4 Heat Treatment
3.5 Freshwater
4. Haul out
4.1 Scraping
4.2 Water-blasting
4.3 Desiccation
5. Refusal of entry into New Zealand

Table 2: The vessel types and scenarios to be considered for non-compliant vessels.

Scenarios	Categories									
Vessel type	1. Yachts/recreational vessels	2. Passenger vessels	3. Fishing vessels	4. Merchant vessels	4.1 Container /Cargo	4.2 Bulk carrier	4.3 Heavy Lift	4.4 Reefer	4.5 Roll-on, Roll-off	4.6 Tanker
Port turn-around time	< 24 hrs	1-14 days	> 14 days							
Port calls in NZ	Single port	Multiple ports								

2.1 DECISION CRITERIA FOR SELECTING MANAGEMENT OPTIONS

The guiding principle for biosecurity risk management is to "*manage risk to achieve the required level of protection that can be justified and is feasible within the limits of available options and resources*" (MAF Biosecurity New Zealand 2006). In choosing appropriate measures to manage vessel biofouling, consideration must be given to the effectiveness of the measure and to any negative effects that it may have on trade, the environment and the New Zealand Government's other priorities, goals and obligations. Guidance on the range of factors that must be taken into account when selecting treatment options is provided by the MAFBNZ Procedures for Risk Assessment (MAF Biosecurity New Zealand 2006). A summary of these considerations is provided in Box 1. For the purposes of this project, they are considered under the five headings described below ("*Decisions criteria*"):

Box 1. MAF guidelines for selecting treatment options to manage biosecurity risks (Section 4.5, MAF Biosecurity New Zealand (2006)).

i. *ensure that the option(s) are based on scientific principles.*

ii. *ensure that measures identified by international standard setting bodies are considered. If there is a scientific justification that an international measure does not effectively manage the risks, measures that result in a higher level of protection may be applied. Alternatively less stringent measures than those recommended in international standards may be applied where there is sufficient justification that the risks can be managed effectively.*

iii. *ensure that the option(s) are applied only to the extent necessary to protect human, plant or animal life or health, or the environment.*

iv. *ensure that negative trade effects are minimised.*

v. *ensure that the option(s) do not result in a disguised restriction on trade.*

vi. *ensure that the option(s) are not applied arbitrarily*

vii. *ensure that the option(s) do not result in discrimination between exporting countries where similar conditions prevail.*

viii. *ensure that the option(s) are feasible by considering the technical, operational and economic factors affecting their implementation*

2.1.1 Feasibility

- How feasible is the option to implement?
- What is the likelihood of success?
- To what degree does the option exist within New Zealand?
- What is the ability of this option to be used throughout New Zealand?

2.1.2 Resources

- Are there sufficient resources, skills and capabilities available to implement this option?
- What level/skill of human resources is required and are they accessible?
- Are the tools/equipment required for the option available/accessible?
- Is there a significant cost associated with the resources required?

2.1.3 Opportunities/Barriers

- Are there other opportunities or barriers to success?
- Is there any uncertainty as to the efficacy of the option?
- What is the regulatory status of the option?

- Are there stakeholder concerns/support for the option?
- Are there public concerns/support for the option?
- Are there any legislative barriers to immediate use of the option?

2.1.4 Strategic fit

- How well does the option fit with the Government's strategies and/or strategies that reflect wider Government obligations?

2.1.5 Net benefit

- What is the overall net benefit of the option including costs, benefits and their likelihoods?

3 Description of the Vessels

3.1 RECREATIONAL VESSELS

New Zealand is a popular destination for international cruising yachts and other small, private craft ("recreational vessels"). Each year, more than 600 recreational vessels arrive in New Zealand from overseas locations (Table 3). Arrival is restricted to 15 ports of entry: Auckland, Bluff, Dunedin (and Port Chalmers), Fiordland (Milford Sound), Gisborne, Lyttelton, Napier, Nelson, New Plymouth, Opua, Picton, Tauranga, Timaru, Wellington, and Whangarei (New Zealand Customs Service, http://www.customs.govt.nz/news/resources/factsheets/Documents/Fact Sheet 32.pdf). Taharoa and Westport are also customs ports of entry in New Zealand, but typically do not process recreational vessels.

Most (91.8 ± 0.7%, range 89 - 97.1%) recreational vessels that enter New Zealand waters from overseas clear customs in the northern-eastern ports of Opua, Whangarei, Auckland and Tauranga (Table 3). Vessels arriving in New Zealand fall into two main categories: foreign-owned vessels coming to visit New Zealand and New Zealand-owned vessels returning from overseas voyages. Foreign-owned vessels comprise around 77% of all entries. This statistic is based on the composite results of samples taken of vessels that entered New Zealand in 2003-04 (*n* = 787 vessels; NIWA unpublished data) and in 2005 - 07 (*n* = 186; Floerl et al. 2008). In the former study, 583 (79%) of 757 vessels that provided information on home country/port were foreign. In the latter study, 86 of the 129 (68%) vessels that provided details were foreign.

The number of vessels and timing of their arrival in New Zealand is determined predominantly by weather conditions in the Pacific, and by specific events such as yachting regattas. The traditional peak time of arrival is October to December (~ 90% of annual arrivals) in advance of the austral tropical cyclone season (Table 3). Customs data for 2009 - 10 show that 472 (68%) of the 692 recreational vessels that entered New Zealand arrived between October and December, with most of those (394 vessels) clearing Customs in Opua or Whangarei (Table 3). During these peak periods, between 8 - 15 vessels (maximum 25) may clear Customs each day. Peaks in the total numbers of arrivals have been associated with America's Cup regattas in 1999/2000 and 2002/2003 (Table 3; Inglis & Floerl 2002; Floerl et al. 2008). Most yachts depart New Zealand between April and June (~ 89% of annual departures; **Error! Reference source not found.**), after the austral cyclone season has ended (Inglis & Floerl 2002; NIWA unpublished data).

3.1.1 Description of the fleet

Yachts and private craft arriving in New Zealand are typically < 20 m in length (89.6% of recreational vessel arrivals, Mean ± S.D. length = 15.6 ± 7.5 m), with a mean dead weight tonnage (DWT) of ~ 25.7 ± 41 DWT (*n* = 181; Figure 2; Inglis et al. 2010). The largest yacht recorded in the MAF commissioned research on vessel biofouling was 65 m long and weighed 390 DWT (Inglis et al. 2010). Most of the vessels (83.5%) were mono-hulled.

Table 3: International recreational vessel arrivals to New Zealand 1998 – 2007 (Floerl et al. 2008; NZ Customs Service 2005-2010 data). Years of record run from July to June the following year (e.g. 1998/1999 = July 1998 to June 1999). Note: For NZ Customs Service data (2005-2010), these data were provided as "small craft", which includes all vessels < 25 m. Therefore, although the majority of small vessels are recreational vessels (yachts and motor yachts) the data may include some small fishing vessels.

Port of entry	1998/99	1999/00	2000/01	2001/02	2002/03	2004/2005	2005/06	2006/07	2007/2008	2008/2009	2009/2010
Opua	272	414	349	373	559	459	461	428	438	428	430
Whangarei	53	79	34	47	43	38	37	48	36	64	82
Auckland	95	150	90	104	97	108	107	116	91	93	98
Tauranga	13	40	14	22	42	7	10	17	16	19	17
Napier/Gisborne	2	3	4	10	6	5	5	2	6	1	4
New Plymouth	3	5	5	3	2	4	4	3	3	2	9
Wellington	4	8	23	12	10	20	13	7	9	6	8
Nelson/Picton	24	15	20	22	33	35	19	36	30	28	28
Lyttelton	0	2	1	0	1	1	0	0	2	0	3
Timaru	2	0	0	0	0	0	0	0	0	0	1
Dunedin	0	0	0	3	0	1	0	4	2	3	0
Bluff	4	2	3	6	4	10	4	5	5	2	12
Total	**472**	**718**	**543**	**602**	**797**	**688**	**660**	**666**	**638**	**646**	**692**

Table 4: Percentage of port calls by vessels of different types within each biofouling management scenario.

Turnaround period (days)	No. of ports	Recreational[†] *n* = 179	Passenger[‡] *n* = 75	Fishing[‡] *n* = 191	Bulker[‡] *n* = 959	Container[‡] *n* = 703	Reefer[‡] *n* = 280	Heavy Lift[‡] *n* = 9	RoRo[‡] *n* = 47	Car-carrier[‡] *n* = 153	Tanker[‡] *n* = 435	LPG carrier[‡] *n* = 25
Rapid (<1)	Single	0	20	18	6	14	10	11	2	7	15	12
Rapid (<1)	Multiple	0	53	4	2	44	21	0	21	65	14	16
Short-term (1-14)	Single	0	9	15	25	8	8	56	13	1	11	0
Short-term (1-14)	Multiple	3.4	17	20	62	31	55	22	47	26	41	36
Long-term (>14)	Single	0	0	14	3	2	3	11	9	0	14	36
Long-term (>14)	Multiple	96.6	1	29	2	1	4	0	9	0	5	0

Source: [†]NIWA unpublished data 2002 - 03, [‡]Lloyds Maritime Intelligence Unit database, NZ Foreign Vessel Visits (> 99 gross tonnes) 2000 - 2005.

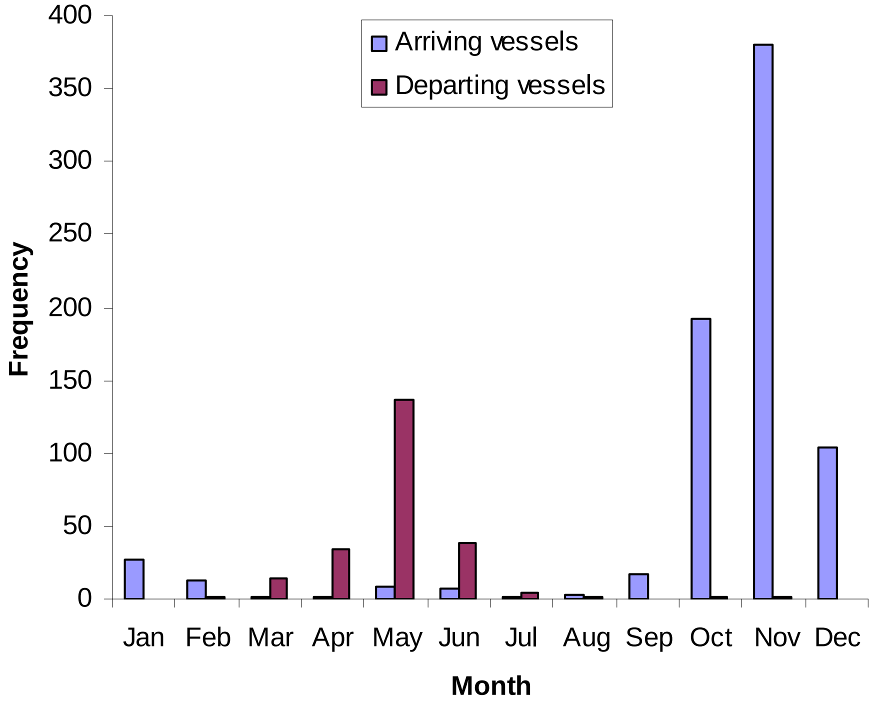


Figure 1: Number of international recreational vessels (foreign and New Zealand vessels) arriving in, and departing from, New Zealand by month in 2002/03 (*n* = 755 arriving and *n* = 233 departing vessels: NIWA unpubl. data).

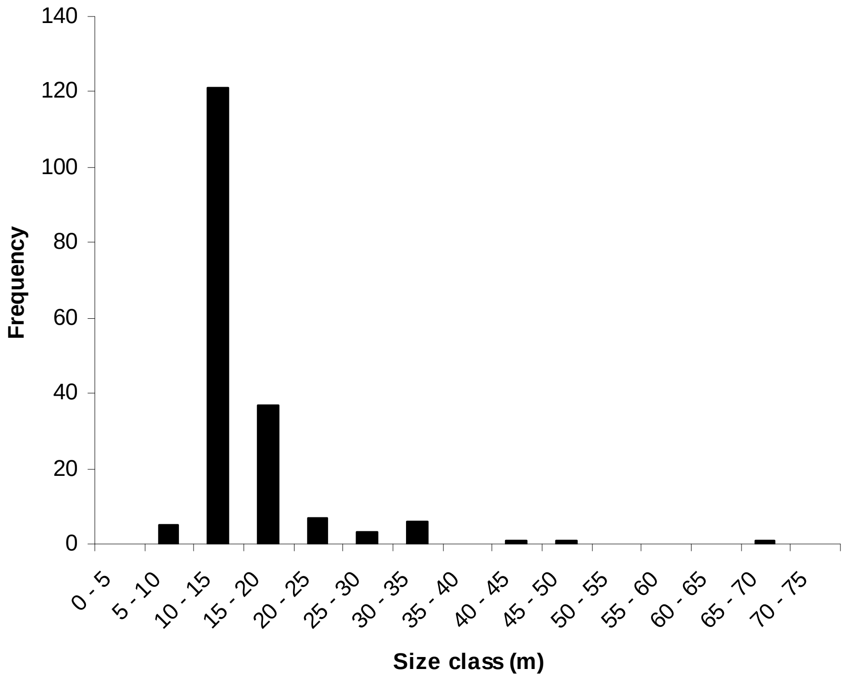


Figure 2: Length size class (m) frequency of a sample (*n* = 182 vessels) of international recreational vessels that arrived in New Zealand in 2005 - 07 (Inglis et al. 2010).

The yachts are generally constructed from fibre-glass and epoxy coatings (> 66%). However, some have hulls made from steel (16%), aluminium (7%), wood (6%), or concrete (2%; Inglis et al. 2010).

3.1.2 Travel patterns within New Zealand

The travel patterns of international recreational vessels within New Zealand are quite variable. The vessels may remain in New Zealand for periods of several days to several years (Table 4). Some visitors travel extensively and visit a large number of destinations, including off-shore islands and coastal embayments, while others moor their yacht in a marina for an extended period, without any further travel. In a few cases, the owners may even fly to their overseas home and return to their vessel after months or years.

A survey of 283 foreign recreational vessels that departed New Zealand in 2002/03 found that they had visited an average (± SE) of 3.9 (± 0.2, range 2 - 29) different locations in New Zealand (NIWA unpublished data), with a mean duration of stay in New Zealand of 258.3 (± 14.4) days (range 3 - 1,339 days). New Zealand Customs Service data for 2006 showed a mean (± SD) stay of 308.7 (± 145.6) days with an average of 24.2 (range 1.8 - 357) days in each port.

All of the foreign recreational vessels captured in the 2002/03 NIWA survey visited more than one port during their stay in New Zealand (Table 4). Most of the vessels (96.6%) remained in New Zealand for longer than 14 days, with only relatively few yachts (3.4% of the sample) reporting shorter periods of residence (Table 4).

3.1.3 Patterns of maintenance and hull husbandry

The maintenance schedules of international recreational vessels are determined by the owner of the vessel relative to their intended pattern or purpose of travel. Many will get the vessel cleaned before embarking on a long voyage (such as a trip to New Zealand) to improve vessel speed. A large proportion (> 90%) of those that enter New Zealand have been dry-docked or re-painted in the 18 months prior to their arrival (Inglis et al. 2010). However, as reduced voyage speed does not have the same economic costs for recreational vessels (particularly sailing vessels) as it does for merchant vessels, there is considerable variation in the frequency with which owners of recreational vessels clean their hull.

In recent years, an increasingly important reason for recreational vessels to visit New Zealand is its attractiveness as a destination for boat maintenance and repair during long voyages (Inglis & Floerl 2002). Three studies, undertaken between 1990 and 2002, provide some indication of the numbers of international recreational vessels that are hauled-out in New Zealand boat yards each year. In 1990, MAF Quarantine Officers surveyed 263 vessels on entry to New Zealand. Fifty-eight percent of the owners indicated that they intended to slip their boat to have "work done" during their stay. Many (38%) were undecided about where this maintenance work would be done, but of those who had decided, Auckland (24%), Opua (15%) and Whangarei (15%) were the most popular locations (Table 5; MAF Quarantine Service 1999). McClary & Nelligan (2001) surveyed 37 boat-yards and vessel cleaning facilities in 2000 - 01. The regional centres in which the largest numbers of international vessels were serviced were Whangarei (34%), Bay of Islands (22%), Auckland (14%), Gulf Harbour (12%) and Tauranga (11%; Table 5). In a 2002 survey of 279 international vessels departing New Zealand, 74% indicated that the vessel had new antifouling paint applied while it had been in New Zealand. The service was done most frequently in Whangarei (24%), Bay of Islands (22%), Gulf Harbour (20%), Auckland (15%) or Tauranga (11%; Table 5; NIWA unpublished data).

Table 5: Percentages of international recreational vessels serviced in haul-out facilities at different locations throughout New Zealand.

Place	MAF Quarantine Service 1999 (*n* = 139)	McClary & Nelligan 2001 (*n* = 676)	NIWA 2002 unpublished data (*n* = 206)
Opua/Bay of Islands	27	22	22
Whangarei	25	34	24
Gulf Harbour/Whangaparoa		12	20
Auckland	39	14	15
Tauranga	6	11	11
Nelson		6	4
Wellington/Mana	1	1	< 1
Picton	1		1
Lyttelton		1	
Coromandel	1		< 1
Napier	1		

3.2 FOREIGN FISHING VESSELS

Seafood exports regularly rank as New Zealand's fourth or fifth largest export earner, with wild-fisheries accounting for a total of $1.42 billion (free on board (FOB) value) in export revenue in 2009 (Statistics New Zealand 2010a). Seventy percent of fish caught in New Zealand's commercial fisheries is taken in deepwater fisheries that operate between 12 nautical miles from shore out to the 200 nautical mile limit of the Exclusive Economic Zone (EEZ). The deepwater fishery contributes > $600 million in export revenues annually. The major species caught are 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).

Fishing vessels that enter New Zealand from overseas are typically either New Zealand flagged vessels returning from foreign fishing grounds or foreign flagged vessels arriving in New Zealand on charter to owners of local quota. Foreign charter vessels (FCV) are used in New Zealand's deepwater fisheries to reduce the operational investment required by New Zealand quota holders to fish these stocks (Ministry of Fisheries 2009). Vessels capable of fishing in deepwater are expensive to build and maintain and, as many of the fisheries are seasonal, it is more economical for local quota holders to charter vessels from outside New Zealand to do the fishing on their behalf during the season. The New Zealand deepwater fisheries industry involves more than 50 seafood companies, which between them operate more than 60 commercial vessels and collectively employ more than 15,000 people (http://www.deepwater.co.nz/n882,125.html). All major New Zealand fishing companies use some FCVs. In 2008 - 09, 30 FCVs caught ~ 198,000 tonnes of fish, representing ~ 47% of the total commercial catch of New Zealand fisheries (Seafood Industry Council 2010). FCVs catch close to 80% of Iwi-owned quota for deepwater species. All FCVs that enter New Zealand must be registered with MAF (formerly the Ministry of Fisheries). The fishing company that charters the vessel is legally responsible for it and how it operates while it is working for them (Ministry of Fisheries 2009).

3.2.1 Description of the fleet

An average of 89 fishing vessels per annum entered New Zealand from overseas between 2000 and 2007 (Piola & Conwell 2010). The main ports of entry were Auckland, Wellington and Nelson (Table 6). The fleet ranges in size from 25 m (110 Gross Tonnage; GT) to over 100 m length (4500 GT;) and includes long-line vessels, deep-water trawlers, factory ships for fish processing and, on occasion, Japanese whale research vessels en-route to the Antarctic. In general, the trawlers and long-line vessels range in size from 40 to 80 m length, whilst the larger vessels (60 to 100 m length) are factory freezer trawlers.

3.2.2 Travel patterns within New Zealand

Fishing vessels spend varying amounts of time in port depending on their operational needs. Reasons for entering port can include the need to unload catch, provision, bunkering, repair and maintenance or crew change-over. Vessels involved in seasonal fisheries may remain in port for extended periods prior to, or following, the main catch period. For vessels that are not compliant with the proposed IHS for vessel biofouling, these long periods of port residence increase the risk that a non-indigenous organisms will establish, but also provide opportunity for a broader range of options to manage biofouling on the vessel (see Section 4).

Between 2000 and 2005, just under half (47%) of the FCVs had just a single port visit during their time in New Zealand (Table 4). Vessels that remained in New Zealand for long periods of time often made large numbers of repeat port visits (> 20), associated with servicing different fishing grounds and operations during different seasonal fisheries. Most port visits (78%) were > 1 day in duration (Table 4). Table 4 suggests a multimodal pattern of port stays, with ~ 42% of visits lasting < 3 days and a second mode of longer port stays (10 to 50 days) accounting for ~ 31% of visits. A number of the very long port stays within the data are FCVs that were confiscated or laid-up in port because of breaches in fishing operations or disputes with crew.

Table 6: International fishing vessel arrivals (including repeat visits) to New Zealand ports during 2000 - 07 (average), 2006 and 2007 (Piola & Conwell 2010).

Port	2000 - 07 average	2006	2007
Whangarei/Marsden Pt	3	7	1
Auckland	28	14	24
Tauranga	7	3	3
Napier	2	1	3
New Plymouth	1	4	2
Wellington	14	13	3
Nelson	19	14	19
Lyttelton	7	10	9
Timaru	3	1	4
Port Chalmers/Dunedin	2	3	5
Bluff	3	4	10
Total	**89**	**74**	**83**

3.2.3 Patterns of maintenance and hull husbandry

Like other types of large commercial vessel, fishing vessels are usually scheduled for hull cleaning and reapplication of antifouling coatings at the time that certification surveys are required by the vessel's classification society(s) (see the following section on *Patterns of maintenance and hull husbandry of merchant and passenger vessels*) or when drag caused by biofouling is affecting the fuel consumption of the vessel. Unlike merchant vessels, however, there has historically been no mandatory regulation or set of rules governing international safety certification requirements for fishing vessels (Det Norske Veritas 2007). Some flag states have required fishing vessels to satisfy particular national regulations, often based on the *Torremolinos International Convention for the Safety of Fishing Vessels Protocol*, 1993. Other flag authorities have accepted that fishing vessels have been equipped with non-conventional SOLAS certificates and surveyed by the Class accordingly. Some jurisdictions (e.g. the European Economic Community) have developed Memoranda Of Understanding (MOUs) that require all fishing vessels operating within their waters to meet specified survey standards. The New Zealand Government is currently considering potential accession to the *Torremolinos Convention*.

The certification and safety requirements for foreign fishing vessels that enter New Zealand waters are currently specified by Maritime New Zealand in Part 46 of the Maritime Rules (Maritime New Zealand 2009). FCVs registered under the New Zealand Fisheries Act are subject to survey if they are not in possession of documents that can be recognised by the Maritime New Zealand under section 41 of the Maritime Transport Act 1994 (i.e. international survey certification documents). The general requirement for fishing vessels is for a renewal survey to be carried out every 4 - 5 years (Det Norske Veritas 2007). There is, however, considerable variation in the schedules of maintenance undertaken by fishing vessels from different flag states.

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

In 1996, the New Zealand Fishing Industry Association adopted a voluntary Code of Practice for chartering FCVs that included measures aimed at ensuring that vessels entering New Zealand waters were “substantially free from biofouling” (New Zealand Fishing Industry Association 1997). Under the Code, New Zealand fishing companies chartering a foreign vessel were obliged to obtain a guarantee from the vessel owner/operator that the hull of the vessel was “substantially free from plant or animal growth” on entry to New Zealand (New Zealand Fishing Industry Association 1997). Where that assurance was not forthcoming, the chartering company had the right to require an inspection at the vessel owner’s cost upon its first arrival in a New Zealand port. Vessels found to have “unacceptable” levels of biofouling could be requested to be cleaned. It is unclear how much compliance there has been with the Code of Practice. In the recent MAF commissioned research on vessel biofouling, 8 of the 11 (73%) international fishing vessels that were surveyed had some macrofouling on their hulls (Piola & Conwell 2010), indicating that the existing voluntary code may not be effective at reducing biofouling to a level that would comply with the proposed IHS.

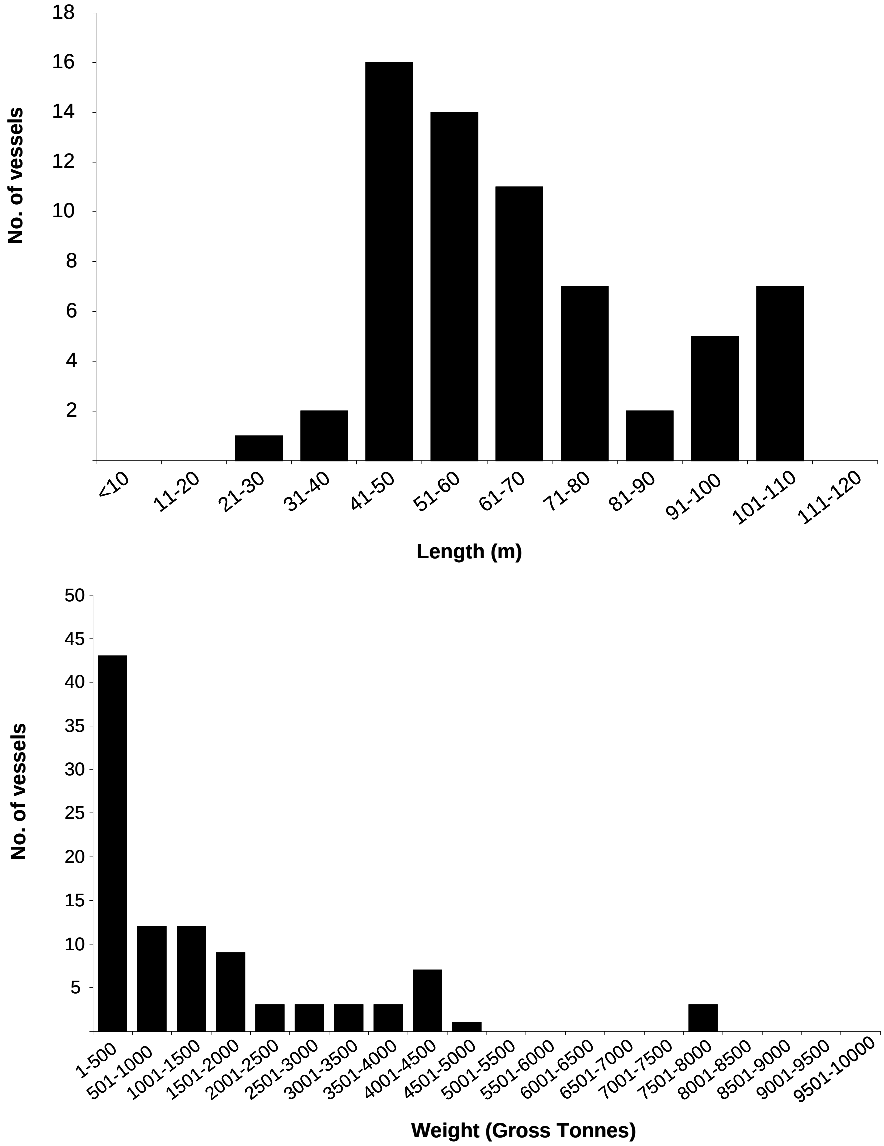


Figure 3: Length (m) and weight (GT) frequency distributions of foreign flagged fishing vessels operating in New Zealand between 2000 and 2005 (Lloyds Maritime Intelligence Unit Seasearcher database 2001 - 2005).

3.3 PASSENGER VESSELS

Cruise tourism is the fastest growing sector of New Zealand tourism (Tourism New Zealand 2010). The number of visits to New Zealand by passenger vessels has increased from around 33 vessel visits in 2004/05 to 81 vessel visits in 2008/09 (New Zealand Customs Service 2009; Tourism New Zealand 2010). Over that time, incoming passenger numbers have increased from approximately 100,000 to over 180,000 per annum. This growth is expected to continue as the world market for cruise tourism increases and as cruise line companies seek alternative destinations during the Northern Hemisphere low season (Tourism New Zealand 2010). The total number of cruise passengers entering New Zealand each year is now comparable to the total number of visitors from China, New Zealand's fourth-largest inbound tourism market (Tourism New Zealand 2010).

Each cruise is worth an estimated $1 million to the New Zealand economy and the industry as a whole contributes more than $182 million per annum to New Zealand's gross domestic product (GDP; Market Economics Ltd 2008). In the 2007/08 year the cruise industry sustained, directly or indirectly, an estimated 2,790 full time equivalent workers (FTE's) in New Zealand (Market Economics Ltd 2008). Passengers are estimated to spend an average of $225 per day in port (Market Economics Ltd 2008).

The New Zealand cruise sector is characterized by four different types of voyage (Cruise New Zealand 2010):

1. Trans-Tasman;
2. Round the World;
3. Expedition;
4. Winter outbound.

These different types of cruises are usually serviced by different categories of vessels and are characterized by different modes of cruise itinerary (Cruise New Zealand 2010).

Trans-Tasman cruises are the most common type of cruise to New Zealand, and involve vessels that visit both Australia and New Zealand on a voyage. Trans-Tasman cruises will often visit more than one port while in New Zealand. Round-the-World cruises involve ships that call into New Zealand as part of a world cruise. Passengers purchase sections or the entire trip. Expedition cruises tend to spend more time in areas of New Zealand that large ships are unable to access, such as New Zealand's sub-Antarctic islands, as well as the smaller inlets and coves around Fiordland National Park and Marlborough Sounds. During New Zealand's colder winter months, outbound cruises take passengers from New Zealand (principally Auckland) to Pacific Island destinations.

Most cruise ships enter New Zealand between October and April. During the Northern Hemisphere winter, the major cruise companies either temporarily reposition some of their vessels in the South Pacific (including Australia and New Zealand) or visit South Pacific ports as they sail through on longer voyages. Itineraries for the cruises are typically set 18 - 24 months before the cruise (King 1999). A key element of the profitability of cruise ship companies is ensuring high rates of berth occupancy to offset the large fixed costs of operating the vessel. To this end, many companies offer heavily discounted rates for early booking, with prices increasing closer to the date of departure (Papatheodorou 2006). This pattern of discounting means that bookings are often made months or years in advance of the cruise (Lieberman & Dieck 2002).

The selection of ports to include in a cruise itinerary is influenced by a range of factors, including the marketability of the itinerary, port accessibility, costs, berth congestion, the behaviour of competitors and the line's experience with previous cruises (King 1999). For turn-around ports (where passengers begin or end a cruise), access to other transport infrastructure (e.g. international airports) and efficient embarkation and disembarkation procedures are important. Although marketability is the key criterion for port selection and may outweigh any operational problems or added costs, cruise line companies tend to be very risk averse because of the substantial costs they may incur from operational difficulties and delays (King 1999).

Disruptions and unexpected delays can be very costly to cruise lines through additional costs, lost revenues and damage to their market reputation. Disruptions that affect turn-around ports can incur costs from the need to rebook flights, hotels, ground transportation, food and drink, and to employ extra staff to cope with disrupted passenger flows. Where there are significant delays or disruptions it is common practice in the industry to offer passengers refunds or heavily discounted tickets for future cruises (King 1999).

3.3.1 Description of the fleet

In 2010 - 11, the New Zealand cruise industry was serviced by 34 vessels (Table 7). Many of these make multiple return visits to New Zealand during the cruise season. The vessels range in size from the 63 m long *Oceanic Discoverer* to the 345 m *Queen Mary 2* (Table 7). Ninety percent of the fleet is larger than 175 m length and weighs more than 20,000 DWT. In general, expedition cruises tend to involve smaller vessels, whilst the largest vessels visiting New Zealand do so as part of a round-the-world tour.

3.3.2 Travel patterns within New Zealand

Cruises that travel around New Zealand usually start from Auckland, Sydney, Melbourne or Brisbane, and will cruise the eastern coastline of New Zealand (Tourism New Zealand 2007). Cruise ships tend to call on the main cruise ports of Auckland, Tauranga, Napier, Wellington, Lyttelton, and Port Chalmers (Dunedin), and may 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). Scheduled cruise ship visits to New Zealand ports for the 2010 - 11 season are summarised in Table 8.

Cruises are on tight time schedules because of their forward schedules and the need for the voyage to integrate with the airline connections of passengers who have booked an "air/sea" package (Lieberman & Dieck 2002). Passengers are cautioned that if they are late reporting to the vessel for the scheduled time of departure that it will sail without them and they will have to meet the costs of getting to a later port to re-join the cruise. Around 41% of cruise passengers in New Zealand arrive in the country by air and board the ship in New Zealand. The remainder arrive on the vessel from overseas ports (Tourism New Zealand 2007).

Around 73% of all New Zealand port visits by passenger vessels are for < 24 h and 88% last < 48 h (Table 4). Cruise passengers tend to have an average of 10 - 12 h ashore in each port (Tourism New Zealand 2007). Between 2000 and 2005, around 29% of visits were to just a single port (often Auckland) and comprised a stop-over on a longer round-the-world cruise (Table 4). The largest numbers of cruises consisted of rapid (< 1 day) or short (1 - 2 days) visits to multiple ports in New Zealand (Table 4). Vessels that remain based in New Zealand for prolonged periods (often expeditionary cruises that undertake multiple voyages while in New Zealand) may have > 20 port visits during their stay.

Table 7: Passenger vessels visiting New Zealand in the 2010-11 season.

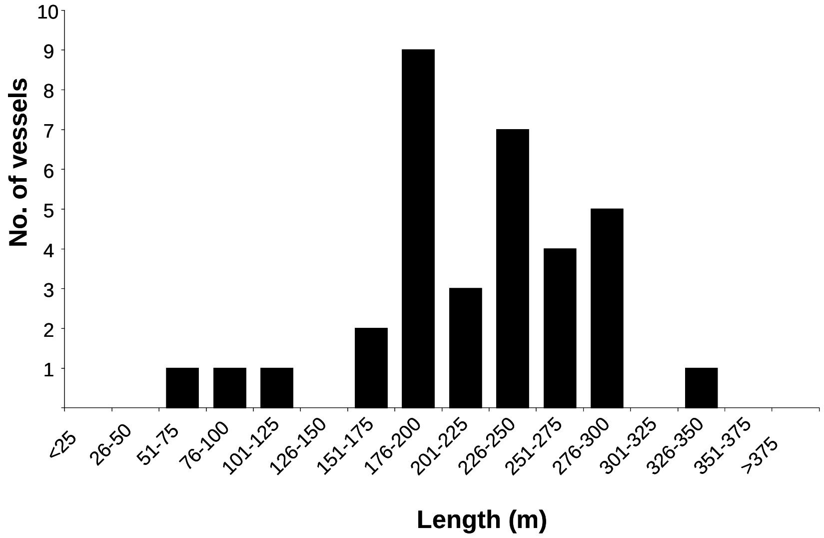
Vessel name	Weight (DWT)	Length (m)	Beam (m)	Draft (m)	Max. Speed (knots)	No. of Passengers	No. of Crew
Amadea	28,856	192.8	24.7	6.2	21	624	243
Amsterdam	62,735	237.8	32.2		22.5	1,380	615
Arcadia	82,972	285.3	32	7.8	22	1,996	886
Asuka II	50,142	241	29.6		21	960	545
Aurora	76,152	270	32.2	7.9	24	2,290	936
Balmoral	43,537	218.2	28.2	7.3	22.5	1,350	471
Crystal Serenity	68,870	250	32.2		22	1,140	655
Dawn Princess	77,000	261.3	32.2	8.1	21	1,950	830
Deutschland	22,496	175.3	23	5.8	20.5	613	240
Diamond Princess	116,000	290	37.5	8.5	24.6	2,670	1,115
Europa	28,437	198.6	24	6.1	21	408	264
Oceanic Discoverer	1,838	63	13	3	14	72	20
Oriana	69,153	260	32.2	7.9	24	1,804	760
Orion	4,000	103	14.3	3.8	16	100	65
Pacific Dawn	77,000	247.2	32.2	7.8	22.5	2,050	900
Pacific Jewel	63,524	245.6	32	8.2	20	2,014	886
Pacific Pearl	63,500	247	32	8.2	21.5	1,800	514
Pacific Princess	30,277	181	25.5	5.8	19.2	670	373
Pacific Sun	47,000	223.4	28.2	7.5	21.7	1,486	670
Pacific Venus	26,518	183.4	25	6.5	20.8	423	180
Paul Gauguin	19,170	156.6	21.6	5.15	18	332	215
Queen Elizabeth	92,000	294	32.2	8	23.7	2,092	900
Queen Mary 2	151,400	345	41	10	30	2,620	1,253
Rhapsody of the Seas	78,491	278.9	32.2	7.6	22	1,998	765
Saga Ruby	24,492	191.1	25	8.6	21	668	380
Sapphire Princess	115,875	288.3	37.5		22.1	2,670	1,100
Seabourn Sojourn	32,000	198	25.6	6.4	22.3	450	340
Seven Seas Navigator	28,550	172.2	24.7	7	20	490	340
Seven Seas Voyager	42,362	204.2	28.8	7	20	700	447
Silver Shadow	28,258	185.9	24.9		21	382	295
Silver Spirit	36,000	186.5	26.2		20.3	540	376
Spirit of Oceanus	4,200	90.6	15.3		16	114	72
Sun Princess	77,000	260.9	25.3	7.9	19	1,950	900
Volendam	61,396	238	32.2	7.3	23	1,432	588

3.3.3 Patterns of maintenance and hull husbandry

(See the following section on *Patterns of maintenance and hull husbandry of merchant and passenger vessels*.)

Table 8: Expected passenger vessel visits during the 2010-11 season (Cruise New Zealand 2010).

Port	Number of visits
Bay of Islands	37
Auckland	92
Tauranga	51
Gisborne	4
Napier	50
Wellington	60
Nelson	0
Picton	11
Kaikoura	5
Lyttelton	60
Akaroa	7
Timaru	1
Port Chalmers (Dunedin)	14
Milford Sound	71
Stewart Island	15



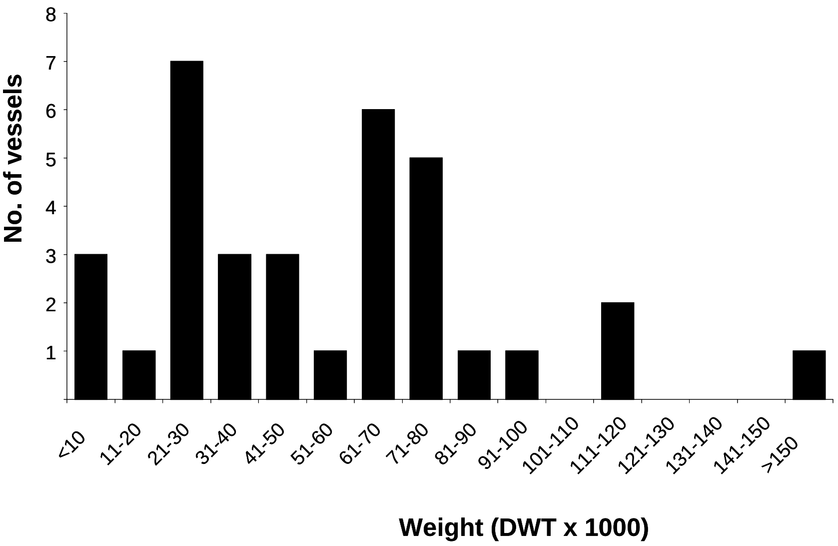


Figure 4: Length (m) and weight (DWT) frequency distributions of passenger vessels due in New Zealand during the 2010-11 season (Cruise New Zealand 2010).

3.4 MERCHANT VESSELS

New Zealand depends on sea-freight for the movement of goods to and from its major international markets. In 2008, New Zealand imported a total volume of 17.0 million tonnes of goods, and exported a total volume of 25.1 million tonnes of goods (Statistics New Zealand 2010). The total value of New Zealand's exports in 2008 was $37.4 billion (FOB) – or approximately 28% of New Zealand's GDP in that year. Nearly all of this volume (99.6%) was carried by sea to overseas markets (New Zealand Shippers' Council 2010; Statistics New Zealand 2010b).

Each year, New Zealand receives 2,500 to 3,000 visits from merchant (cargo) vessels, of which almost half (49.8%) are by container or general cargo vessels (New Zealand Customs Service 2010). Roll-on Roll-off ("RoRo" – 17%) and bulk carriers (16%) make up the next largest numbers of port visits by merchant vessels (Table 9). However, most of our export and import trade by volume (~ 61%) is shipped as bulk commodities in bulk carriers or tankers (New Zealand Shippers' Council 2010).

More than half of all freight-related vessel visits are to the major ports of Auckland (22%), Tauranga (17%) and Lyttelton (12%; Table 9). There are, nevertheless, 15 ports or terminals throughout New Zealand that receive regular visits from merchant vessels of different types (Table 9). In the following sections we describe the operating characteristics of different classes of merchant vessel that visit New Zealand and patterns in their modes of operation.

3.4.1 Description of the fleet

Bulk carriers

A bulk carrier is a ship that carries loose, dry cargo in bulk, rather than in barrels, bags, containers, etc. Around 61% of New Zealand's import and export cargo is transported in bulk or break-bulk form (New Zealand Shippers' Council 2010). Typical cargos can include logs, unconsolidated wood chips, grain, ore, sand, cement, coal, gypsum, etc. Each year New Zealand ports receive visits from more than 1,000 bulk carriers that transport bulk cargo into and out of New Zealand (Table 9). The largest numbers of visits by bulk carriers occur to the ports of Tauranga, Whangarei, Napier, Lyttelton and Bluff (Table 9).
Six general classes of bulk carrier can be characterized (
Table 10, MAN Diesel 2007a). More than 70% of the global fleet – in terms of the number of ships – is < 55,000 DWT, with 32% being vessels in the Handysize class (MAN Diesel 2007a). Most bulk carriers that enter New Zealand are in the Handysize (~ 47% of visits) and Handymax classes (~ 37% of visits;
Table 10). Globally, there is an increasing trend toward use of larger bulk carriers on the main shipping routes, with most (77%) new carriers being in the Handymax size or larger (MAN Diesel 2007a).

Table 9: Total numbers of visits to New Zealand ports by different classes of merchant vessel between 2000 and 2005.*

Port	Bulk	Container & General Cargo	Reefer	Heavy Lift	RoRo	Tanker	Total
Auckland	304	5,032	425	11	1454	379	7,605
Tauranga†	1,320	3,168	517	0	295	325	5,625
Lyttelton	592	2,131	264		974	297	4,258
Wellington	206	1,423	201		1,473	344	3,647
Nelson	417	1,073	327		1,484	117	3,418
Napier	624	1,755	513		173	107	3,172
New Plymouth	191	568	222		6	703	1,690
Dunedin‡	248	1,019	45		115	34	1,461
Whangarei	683	237	211		16	210	1,357
Timaru	174	535	9		10	395	1,123
Bluff	514	363	14	1	17	86	995
Gisborne	223	101	138		7	1	470
Picton	81				9		90
Westport	9				21	2	32
Taharoa Terminal	14						14
Total	**5,600**	**17405**	**2886**	**12**	**6054**	**3000**	**34957**

*Includes all vessel visits, not just ports of first arrival.
†Includes Mount Maunganui, ‡Includes Port Chalmers
Source: Lloyds Maritime Intelligence Unit database, NZ Foreign Vessel Visits (> 99 gross tonnes) 2000 - 2005.

Table 10: Dimensions of bulk carriers of different classes (MAN Diesel 2007a) and the percentage of vessels in each class that service New Zealand.

Bulk carrier type	Dimensions (metres)	Ship size (DWT)	[1]Percentage of vessels visiting NZ (2000-2005) (*n* = 821)
Small	Overall ship length up to ~ 115 m	Up to 10,000	1
Handysize	Scantling draught up to ~ 10 m	10,000 – 35,000	47
[2]Handymax	Overall ship length max. ~ 190 m	35,000 – 55,000	37
[3]Panamax	Ship breadth equal to max 32.2/32.3 m Overall ship length up to 289.6 m Passing ship draught up to 12.04 m	60,000 – 80,000	15
[4]Capesize	Breadth approx 43 - 45 m for 90,000 - 180,000 DWT	80,000 – 200,000	< 1
VLBC – Very Large Bulk Carrier	Overall ship length > 300 m	> 200,000	0

[1]Source: Lloyds Maritime Intelligence Unit Seasearcher database 2000 - 2005
[2]A Handymax vessel is typically between 150 - 200 m in length, though certain bulk terminal restrictions such as those in Japan mean that many Handymax ships are just under 190 m in overall length.
[3]Represents the largest acceptable size able to transit the Panama Canal. Maximum size is determined principally by the dimensions of the canal's lock chambers, each of which is 33.53 m wide by 320.0 m long, and 25.9 m deep. The usable length of each lock chamber is 304.8 m. The available water depth in the lock chambers varies, but the shallowest depth is at the south sill of the Pedro Miguel Locks, and is 12.55 m.
[4]An ill-defined vessel standard that refers to vessels incapable of using the Panama or Suez canals, not necessarily because of their tonnage, but because of their size (i.e. they exceed the dimensions of the canal facilities).

3.4.2 Patterns of operation within New Zealand

The time required to load and unload a bulk carrier depends on the size of the vessel and the nature and volume of cargo. Typical periods of stay in New Zealand ports range between 1 to 3 days (Table 4). Around 66% of the bulk carriers that enter New Zealand waters visit more than one port during their voyage (Table 4)

The bulk freight market is very volatile and demand for vessels can vary according to the type of commodity being carried, its market value and the availability of suitable vessels on the world market. In 2008, for example, high demand for bulk carriers pushed charter rates up so high that a significant volume of New Zealand's export logs were exported in containers (New Zealand Shippers' Council 2010).

Container vessels

Three classes of container vessels visit New Zealand regularly: Small Feeders, Feeders and Panamax vessels (Table 11). These range in size from around 90 m length and 5,000 DWT to over 280 m length and 54,000 DWT. Most (82%) visits are currently made by vessels that are < 35,000 DWT in size (Table 11). The capacity of container vessels is usually described in terms of the number of 'twenty-foot equivalent units' (TEUs) the vessel can carry. TEU is a standard measure of container volume. One twenty-foot container is equivalent to one TEU. One forty-foot container equals two TEU, etc (New Zealand Shippers' Council 2010).

Table 11: Dimensions of container vessels of different classes (MAN Diesel 2005) and the percentage of vessels in each class that service New Zealand.

Container vessel type	Dimensions	Ship size (DWT)	Number of containers (TEU)	†Percentage of vessels visiting NZ (2000-2005) (*n* = 495)
Small Feeder	Length range 105 – 150 m	5,700 – 13,500	Up to 1,000	36
Feeder	Length range 155 - 200 m	16,000 - 31,000	1,000 – 2,500	46
Panamax	Length range 220 – 293 m	37,000 – 54,000	2,500 – 5,000	18
Post-Panamax	Length range 280 – 335 m	54,000 – 93,000	4,500 – 8,000	0
Suezmax	Length range 400 m	137,000	12,000	0

†Source: Lloyds Maritime Intelligence Unit Seasearcher database 2000 - 2005

At present, the average-sized container vessel calling at New Zealand ports has a capacity of ~ 2,700 TEU. The largest ship that calls regularly at New Zealand has a nominal capacity of 4,100 TEU (Table 11, New Zealand Shippers' Council 2010). A 5,000 TEU and a 4,500 TEU container vessel called at New Zealand ports in December 2009 and April 2010 respectively, but there is currently no scheduled service using ships of this size (New Zealand Shippers' Council 2010).

Globally, there is a trend toward use of larger container vessels. About 28% of the current global fleet of container ships is Post-Panamax size or larger. By 2014, the total number of ships in these larger classes will increase to ~ 33% of the world fleet, and ~ 67% of total fleet capacity (New Zealand Shippers' Council 2010). It is anticipated that more vessels in the Post-Panamax range will be redirected to New Zealand, as major trading lanes become serviced by even larger ships (i.e. up to 14,000 TEU; New Zealand Shippers' Council 2010). At present, New Zealand's four largest container ports - Auckland, Tauranga, Lyttelton, and Otago - can accommodate ships in the range of 4,500 to 5,000 TEU, but they do not have the capability to handle ships larger than this (New Zealand Shippers' Council 2010). Investment in infrastructure and capital works is planned or underway at several of these ports to cater for Post-Panamax size vessels.

3.4.3 Patterns of operation within New Zealand

The busiest container terminals in New Zealand, in terms of the number of ship visits, are at the ports of Auckland, Tauranga, and Lyttelton (Table 9; New Zealand Shippers' Council 2010). The container shipping business is structured around tight time-schedules and has a focus on rapid and reliable delivery of cargo (Table 4). Ports are under strong commercial pressure to increase the efficiency of cargo handling and thereby reduce the time that vessels are in port. Between 1989 and 1999, the Port of Auckland reduced its average turn-around time for container vessels from 39 to 14.9 h (Bailey 1999).The time taken to load and unload cargo depends on the size of the vessel and number of TEUs that are to be handled. The New Zealand Shippers' Council (2010) estimates that:

- vessels smaller than 2,600 TEUs have an average port call of < 1 day;
- vessels between 4,300 and 8,500 TEUs will generally be in port for between 1 and 2 days;
- vessels up to 11,000 TEUs will have average port calls of ~ 2.4 days.

Most port visits in New Zealand are currently < 1 day (58%), < 2 days (77%) or < 14 days (97%) in duration (Table 4).

The global container shipping business is very competitive, and profit margins are generally quite small (Notteboom 2006). Shipping lines have developed a strong focus on designing services that have short transit times and a high degree of reliability in scheduling. Delays can incur costs to the shipping line through unproductive vessel time and the need to reschedule forward itineraries. Delays also affect the reliability of the container services negatively and can result in costs to the freighter as a consequence of delayed delivery, additional inventory costs and, in some cases, additional production costs for which compensation may be sought from the shipping line (e.g. where production has to stop due to a late delivery of materials; Notteboom 2006).

As a liner shipping service typically consists of a set of round-trips made by individual vessels, delays in one of the segments of the trip have cascade effects in the total voyage (Notteboom 2006). Shipping lines typically have very limited contingency in their schedules for delays. 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).

Tankers

Tankers are cargo ships that carry bulk liquid cargos. The Lloyds Maritime Intelligence Unit (LMIU) maintains data on 17 sub-types of tanker, although five sub-types are most common (MAN Diesel 2007b):

- Chemical tankers (includes vessels capable of carrying many types of chemical cargoes, including petroleum products and vessels that are designed to carry very specific chemical products);
- Combination carriers (capable of carrying ore or solid cargo and crude oil alternatively);
- Product tankers (carries products refined from crude oil and other fluids such as wine, juice, etc);
- Crude oil tankers; and
- Liquefied gas tankers (e.g. LPG, LNG).

Tankers visiting New Zealand are mostly combination carriers, crude oil tankers or product tankers (Table 12) in the Handysize and Handymax classes (Table 13). These vessels typically range in size from around 120 (~ 10,000 DWT) to 180 m length (~ 50,000 DWT; Table 13).

The design characteristics of gas carriers (LPG and LNG tankers) are quite different from other types of bulk liquid carriers. LPG tankers have an average overall length of ~ 120 m. Twenty three of the 25 LPG tankers in the LMIU SeaSearcher database that visited New Zealand between 2000 and 2005 were < 8000 DWT. Visits by LPG tankers occurred predominantly to facilities in the ports of Taranaki (60% of all LPG tanker visits between 2000 and 2005), Lyttelton (24%) and Otago (12%) and were typically of < 1 (28%) or < 2 days' duration (36%; Table 4).

Table 12: Number of tankers of different sub-types that visited New Zealand ports from 2000 to 2005.

Tanker sub-type	LMIU Subtype Code	†Number of vessels visiting NZ (2000 - 2005)
Combination (Chemical/oil) carrier	CO	117
Crude oil tanker	CR	98
Product tanker	PD	93
Chemical tanker	CH	40
LPG Tanker	PG	26
Asphalt tanker	AS	9
Tanker (non-specific)	TA	3
Naval Auxiliary	NA	2
Floating Storage	FS	1
Acid Tanker	AC	1

†Source: Lloyds Maritime Intelligence Unit Seasearcher database 2000 - 2005

Table 13: Dimensions of tankers (not including liquid gas carriers) of different classes (MAN Diesel 2007b) and the percentage of vessels in each class that visit New Zealand.

Tanker vessel type	Dimensions	Ship size (DWT)	†Percentage of vessels visiting NZ (2000-2005) (*n* = 363)
Small	Length range 100 - 116 m	5,000 – 8,000	2
Handysize	Length range 124 - 170 m	10,000 – 25,000	24
Handymax	Length range 176 – 183 m	30,000 – 50,000	47
Panamax	Length range 229 m	60,000 – 70,000	< 1
Aframax	Length range 244 m	85,000 – 105,000	7
Suezmax	Length range 250 – 274 m	115,000 – 165,000	20
VLCC – Very Large Crude Carrier	Length range 333 m	260,000 – 319,000	0

†Source: Lloyds Maritime Intelligence Unit Seasearcher database 2000 - 2005

Table 14: New Zealand trade in bulk liquids (2006).† Port calls include international and domestic trans-shipment of products.

Petroleum bulk liquids	Port calls	Millions of Tonnes
Crude oil and condensate loadings (Taranaki)	37	1.1
Crude oil imports (Marsden Point)	49	4.5
Product, condensate & blendstock transfers (Marsden Point)	134	3.0
Finished product discharges (New Zealand ports)	300	3.6
Sub-total	**520**	**11.8**
Non-petroleum bulk liquids		
Methanol exports (Taranaki)	8	0.36
LPG (4 ports)	161	0.17
Chemicals & other bulk liquids	170	0.35*
Sub-total	**339**	**0.88**

†Source: (Ministry of Transport 2007)
*Includes acids and alkalis, solvents, tallow and vegetable oils

The largest numbers of visits by tankers to New Zealand are to the ports of Taranaki, Timaru, Auckland and Wellington (Table 9). However, the range of products carried and tanker types servicing New Zealand varies among ports. For example, as the main service port for New Zealand's offshore oil and gas industry, a large proportion of tanker visits to the Port of Taranaki (Westgate) are by vessels equipped to carry petroleum or gas products such as crude oil, condensate, natural gas and LPG. PrimePort Timaru, by comparison, handles a wider range of bulk liquids. It is New Zealand's largest export port for bulk tallow, but also handles significant volumes of refined fuel, bitumen, molasses, bulk chemicals, and vegetable oils (PrimePort Timaru Ltd 2005).

Most crude oil tanker (sub-type 'CR') visits to New Zealand are to the Marsden Point Refinery in Whangarei Harbour (> 83% of all CR visits to New Zealand). Almost all of the Suezmax class tankers visiting New Zealand between 2000 and 2005 were crude oil tankers servicing the Marsden Point Oil refinery. Worldwide, the Suezmax class of tankers is dominated by crude oil tankers (MAN Diesel 2007b).

The duration of port visits by tankers is related to the size of tanker and type of product being loaded or unloaded. Over half of all product, chemical, and combination tanker port calls are of 1 - 3 days duration (Table 4). Smaller tankers (often carriers of refined petroleum products) tend to have shorter port calls of < 1 day (Table 4). Over 60% of tankers visiting New Zealand make calls to more than one port during their time in the country (Table 4).

Table 14 provides an overall summary of the numbers of New Zealand port calls (first arrival and domestic trans-shipment) made by international tankers in 2006 and the types and volumes of product carried by them. The greatest numbers of port calls were made by tankers carrying refined petroleum products (Table 14). Bulk liquids that were not petroleum or gas products (acids and alkalis, solvents, tallow and vegetable oils) accounted for around 16% of all port calls (Table 14).

Reefers

Reefers are cargo vessels that transport goods that must be kept at temperatures other than ambient temperature (usually cooler). Conventional Reefers carry both palletized cargo ("break-bulk" cargo) and cargo stored loose in holds. Modern Reefers are also designed to carry containerized cargo (refrigerated containers), with some vessels capable of carrying up to 400 TEU. Reefers that regularly transport fruit or other fresh product often use Controlled Atmosphere (CA) systems in their holds. CA systems typically use inert gases (most commonly nitrogen) to lower oxygen concentrations and, thereby, slow respiration and the decay of fresh produce.

Because reefers typically carry perishable goods, the value of their cargo is greatly dependent on prompt delivery (New Zealand Shippers' Council 2010). Around 80% of visits by reefers include calls to more than one port (Table 4) and most port calls (69%) are of > 1 day duration (Table 4).

3.4.4 Patterns of maintenance and hull husbandry of merchant and passenger vessels

Because of the costs involved in dry-docking large vessels (see Section 4.4), owners of merchant and passenger vessels usually schedule hull cleaning and reapplication of antifouling coatings at the time that certification surveys are required by the vessel's classification society(s) or when urgent repairs are needed. Classification societies are organisations that establish and apply technical standards for the design, construction, and survey of vessels and offshore structures. Most (94%) commercial vessels operating internationally belong to one of several societies that are part of the International Association of Classification Societies, IACS (Takata et al. 2006). Classification society rules include requirements for periodic hull surveys that are aimed at ensuring the safety and structural integrity of vessels.

Passenger vessels

Passenger vessels have to follow stricter regimes of survey and certification than other types of merchant ship. A renewal survey has to be carried out each year for passenger vessels compared to every 5 years for other merchant vessel types (Knapp & Franses 2006). Renewal surveys involve detailed inspection of items related to the vessel's certification to ensure that it is fit for the service for which the ship is intended. A satisfactory renewal survey leads to the issue of a new certificate and often involves dry docking the vessel (Knapp & Franses 2006). In general, passenger vessels routinely enter dry-dock every 2 - 3 years to satisfy certification requirement (Lyons 2007). However, because biofouling can accumulate between dry dockings and can reduce fuel efficiency, some companies also conduct interim in-water cleaning of the vessel's hull (Takata et al. 2006). Because of the potential loss of revenue when the vessel is out of operation, in-water hull cleaning is typically done while the vessel is loading or unloading at port (Bohlander 2009).

In the MAF commissioned research on vessel biofouling more than 80% of the passenger vessels in the sample ($n = 50$) had been dry-docked or re-painted in the 18 months prior to arrival in New Zealand (median = 244 days since last dry dock; Inglis et al. 2010). This servicing occurred at a range of locations throughout the world. The most commonly cited locations for dry-docking were in the Northeast Atlantic (13 vessels), Mediterranean (9 vessels) and Northwest Pacific (8 vessels; Inglis et al. 2010). Five passenger vessels had their hulls cleaned in-water between scheduled dry-dock surveys (Inglis et al. 2010).

Merchant vessels

For dry bulk carriers, the frequency of visual inspections required by classification societies is around 6 per year. These are mostly visual inspections of safety and hull integrity that are carried out above the water. For most other cargo ships, it is ~ 5 inspections per year (Knapp & Franses 2006). The exception is tankers (oil and chemical tankers) which have around 11 visual inspections per year, although this varies with the type and age of the vessel. As the age increases (above 10 or 15 years), the frequency of industry inspections can increase (Knapp & Franses 2006). For all merchant vessel types, dry-docking is required every 5 years as part of the requirements of a “Special” survey for renewal of certification (International Association of Classification Societies 2010). Some large vessels can be dry-docked with a full cargo load, but there is greater risk involved since great stress is put on the vessel structure. In most cases the vessel will enter the dry dock free of cargo. During dry dock all the compartments of an LNG and LPG carriers are kept gas free.

Almost half of the merchant vessels surveyed on entry to New Zealand in the MAF vessel biofouling risk characterisation study reported they had last been dry-docked in the North-West Pacific. Other significant regions for vessel servicing were South East Asia (24%), Southern Australia (6%), the Baltic (5%) and New Zealand (5%; Inglis et al. 2010).

Most merchant vessels currently use conventional self-polishing antifouling coatings that contain biocides to prevent build up of biofouling organisms (Inglis et al. 2010). The service life of self-polishing systems is proportional to the thickness of the coating layer on the hull. Coating application and thickness are therefore tailored to a vessel’s survey schedule and/or operations forecast. High-quality coating systems can provide biofouling protection for periods of up to 5 years. However, new antifouling coatings are being developed that may further extend the in-service period of vessels and reduce the frequency of dry-docking. For example, surface treated coatings (STC; e.g., Ecospeed) are a new generation of antifouling coatings that do not contain biocides. They are extremely hard, durable coatings that are designed to be cleaned regularly while the vessel is in the water. Initial trials suggest that STCs will provide protection against corrosion for 25 years, reducing the need for dry-docking. As the coatings contain no specific measures to reduce settlement and growth of biofouling organisms, they require regular underwater grooming to keep them free of macrofouling (Hydrex 2009).

3.4.5 Costs of detention or delay of merchant and passenger vessels

Many of the management options described in Section 4 require the vessel to be present in port or in a containment facility for an extended period of time resulting in potential delays to its scheduled itinerary. The costs of delay to the operator of large commercial vessels can be substantial. They can include:

- loss of earnings from a voyage (through non-fulfilment of a charter);

- loss of opportunity (i.e. revenue lost from other potential voyages as a result of detention or delay);
- third party claims for compensation (from cargo owners or members of the crew in response to personal financial losses) and the costs of any associated litigation;
- increase in bunkering costs (by increasing vessel operating speed to make up time);
- increase in port costs through the need to re-schedule the vessel's itinerary;
- loss of confidence from potential charterers or customers;
- higher subsequent insurance premiums; and
- lowering of the owner's credit rating (SSY Consultancy & Research Ltd 2001).

The estimated operating costs (fuel, etc.), time charter costs (the daily cost of the vessel itself) and costs associated with berthage and lay-up of different types of vessel are presented in Table 15. Delays at sea are likely to incur both time charter and operating costs, while in-port delays will incur time charter and berthage costs. The daily operating cost of a vessel can be greater than NZ$21,000 per day for a Panamax size vessel. Time-charter costs (representing lost revenue for charter of the vessel) range between NZ$7,000 for a Small Feeder container vessel to over NZ$50,000 for a Panamax size vessel or passenger ship (Table 15). Marine service charges and berth hire for extended periods can also involve substantial charges to the vessel operator amounting to tens of thousands of dollars (Table 15).

3.4.5.1 Passenger vessels

For passenger vessels, delays can also incur costs from the need to rebook flights, hotels, ground transportation, shore-based tours and concessions, food and drink, and to employ extra staff to cope with disrupted passenger flows. Where there are significant delays or disruptions it is common practice in the industry to offer passengers refunds or heavily discounted tickets for future cruises (King 1999).

Kite-Powell & Hoagland (2002) estimated the direct costs associated with delay of passenger vessels. The daily operating cost of a typical passenger vessel (in 2001) was estimated at US$20,000 (~ NZ$25,000). This is likely to include costs associated with port expenses (10 - 13% of total operating costs), bunkering (9 - 13%), provisioning for passengers and crew (14 - 23%), insurance (2 - 4%), crew wages (23 - 32%), consumables (11 - 17%) and other miscellaneous expenses (8 - 13%; King 1999). Actual operating costs are likely to vary greatly among vessels, depending on their size and market (e.g. luxury versus package cruises; King 1999). For example, the world's largest cruise ship, the M/S Freedom of the Seas has operating costs estimated at US$1 million per day (~ NZ$1.3 million). (http://cruises.lovetoknow.com/wiki/Biggest_Cruise_Ship).

The daily cost of charter (time-charter cost) of a passenger vessel was estimated by Kite-Powell & Hoagland (2002) at US$40,000 (~ NZ$50,000). In addition, because of the schedule constraints of passenger vessels, Kite-Powell & Hoagland (2002) applied a financial penalty of US$100,000 (~ NZ$125,000) when passenger vessels missed their scheduled port arrival time by more than three hours. These costs do not include the lost opportunity costs of expenditure by passengers and crew while the ship is delayed. These have been estimated at NZ$225 per passenger per day (Market Economics Ltd 2008).

3.4.5.2 Merchant vessels

Container vessels

The operating costs of container vessels range from around NZ$5,700 per day for a 1200 TEU ship to > NZ$20,000 per day for Panamax size ship (Table 15). Time charter rates are highly variable and range from NZ$5,000 per day for a 1,200 TEU vessel to over NZ$50,000 per day for an 8,500 TEU vessel (Table 15).

Aside from the direct costs associated with the vessel's operations, Notteboom (2006) estimates that a delay of one day incurred by a single TEU with a load value of €40,000 (~ NZ$70,000) typically results in the following indirect costs:

1. opportunity costs (3 – 4% per year) = €3 – 4.5 per TEU per day (~ NZ$5.30 - 7.90); and
2. economic depreciation (typically 10 – 30% per year for consumer products) = €10 – 30 per TEU per day (~ NZ$18 – 53 per day).

One day of delay for a post-Panamax vessel carrying 4,000 full TEUs, therefore, implies extra costs on the goods of at least €57,000 (~ NZ$100,700) at 3% opportunity cost and 10% depreciation, which is much higher than the charter rate per day for a vessel of this size (Notteboom 2006).

For perishable cargo (e.g. fresh produce, chilled meat, etc), the depreciation costs can be substantially greater and increase exponentially with period of delay, as the value of the product diminishes (New Zealand Shippers' Council 2010). For large vessels containing perishable goods the estimated indirect costs can amount to daily losses in excess of NZ$100,000 (Notteboom 2006).

Bulk carriers

The type of cargo, ship size, age, demand and travel route all influence the charter costs for bulk carriers. Time charter costs can range from NZ$7,000 to > 25,000 for a Handysize class vessel and between $17,000 and 70,000 per day for a Capesize vessel (Table 15).

Table 15: Estimated operating costs (NZ$/day), time charter rates, port charges and rates for lay-up for merchant vessels of different types.[a]

Vessel category		Operating cost	Time charter cost	Marine Service Charges[b]	Berth hire[c]	Lay-up after 7 days[d]
Dry Bulk						
	Small			10,100	800	2,600
	Handysize	3,700	7,400	24,000	2,000	6,200
	Handymax	4,900	9,900	35,000	2,900	9,100
	Panamax	6,200	11,800	49,000	4,100	12,700
	Capesize	8,700	17,400	88,000	7,300	22,700
Container						
	Small Feeder	5,700 - 6,200	4,900 - 35,000	12,000	1,000	3,100
	Feeder	7,000 - 12,400	5,500 - 39,500	28,000	2,300	7,200
	Panamax	7,400 - 19,900	8,000 - 50,000	48,000	4,000	12,500
Tanker						
	Small	-	-	6,900	600	1,800
	Handysize	-	-	15,600	1,300	4,000
	Handymax	-	16,800	39,100	3,300	10,100
	Panamax	7,400	19,600	47,000	3,900	12,100

Aframax	8,700	22,300	81,700	6,800	21,100
Suezmax	9,900	32,300	107,200	8,900	27,700
RoRo/Car carrier	9,900	19,900	46,500	3,900	12,000
LPG tanker (mid-range)	8,910	26,200	5700	500	1,500
Reefer (500kCuFt)	4,900	14,200			
Passenger	25,000	50,000			

[a] Values are only indicative as operating costs and time charter rates will vary according to market demand, and prices for bunkering, labour and capital depreciation. For some very large vessels (e.g. Panamax size or larger) extended lay-up periods are unlikely to occur at berth because of limited berth space. These vessels would more likely be directed to holding anchorages.
[b]Based on rates given for the Ports of Auckland. Calculated as $1.20 per GRT for 24 h (http://www.poal.co.nz/shipping_cargo/price_schedule/)
[c] Based on rates given for the Ports of Auckland. Calculated as $0.10 per GRT for 24 h (http://www.poal.co.nz/shipping_cargo/price_schedule/)
[d]Based on rates given for the Ports of Auckland. Calculated as $0.31 per GRT for 24 h (http://www.poal.co.nz/shipping_cargo/price_schedule/)
Sources: Abbott et al. 2000; Kite-Powell & Hoagland 2002; OECD Maritime Transport Committee 2003; Maritime Strategies International Ltd 2010; New Zealand Shippers' Council 2010.

3.5 EFFECTS OF BIOFOULING ON OPERATING COSTS AND GREENHOUSE GAS EMISSIONS

Biofouling increases the frictional drag across a vessel’s hull and reduces the speed that the vessel can achieve for a given power (Buhaug et al. 2009). As fouling increases, more fuel is consumed to achieve a given speed and emissions from the consumption of diesel fuel are increased. Over periods of 3 - 5 years, between dry docking, the average reduction in speed associated with biofouling is ~ 5%, resulting in the need to increase power by ~ 15% to maintain cruising speed (Buhaug et al. 2009). According to Abbott et al. (2000), most ships deal with this by allowing speed to drop as the hull fouls, rather than by expending more fuel. This increases the journey time meaning there is a need take on more fuel and freshwater with a corresponding decrease in payload. The increase in costs associated with the greater journey time has been estimated at between 58 and 77% (Abbott et al. 2000). Vessel operators must, therefore, balance the costs of increased journey time or fuel consumption against the costs associated with more regular renewal of the antifouling coatings (which requires dry docking) or regular in-water cleaning. The cost of dry docking and antifouling can amount to between 1 and 2 months’ operating profit of the ship (see also Section 4.4), so an increase in the frequency with which it is done can have a significant impact on profitability (Abbott et al. 2000).

The IMO has recently (2003) adopted a range of amendments to the International Convention on the Prevention of Pollution from Ships (the “MARPOL” Convention) that detail policies and practices related to reducing greenhouse gas emissions from ships. These include new requirements for the sulphur content of fuels and standards for the emission of NOx from diesel engines. Advances in hull design and engine efficiency are expected to provide the greatest operational reductions in greenhouse gas emissions from shipping over the next two decades (Buhaug et al. 2009), but better hull husbandry may also contribute to reduced emissions.

3.6 DISTRIBUTION OF BIOFOULING ON VESSELS

Biofouling does not accumulate homogenously on the hulls of vessels that operate within the normal service life of their antifouling coatings. Between 80 and 90% of the biomass and diversity of fouling assemblages may typically be found in niche areas of the hull (Inglis et al. 2010); recessed areas that are protected from drag as the vessel moves through the water or in which the antifouling coating has been compromised. Niche areas can include, but are not limited to the waterline, sea chests, bow thrusters, propeller shafts, inlet gratings, jack-up legs, moon pools, bollards, braces and dry-docking support strips. Vessels that have been laid up for extended periods or which have exceeded the service life of the antifouling coatings may have accumulated a greater biomass of biofouling across a larger range of hull surfaces.

Vessels that are non-compliant with the proposed IHS for vessel biofouling are likely to present a range of fouled conditions, from light patch or "spot" fouling in niche areas through to vessels that have biofouling across the entire hull. These different situations are likely to require different approaches to management.

4 Options for Managing Biofouling on Non-compliant Vessels

4.1 NO ACTION TAKEN

4.1.1 Description of the management option

The "no action taken" option allows the vessel to continue with its intended itinerary without further management/intervention.

As there are currently no mandatory requirements to control biofouling on vessels entering New Zealand waters, this option reflects current management practice and is the baseline option against which other options are compared.

4.1.2 Feasibility

The "no action taken" option can be implemented at any port of entry in New Zealand for any vessel type.

However, the "no action taken" option does not reduce the probability that harmful organisms within the biofouling may establish populations in New Zealand. Because no mitigation occurs, the longer the vessel remains in New Zealand the greater is the likelihood that species within the biofouling will spawn or escape from the vessel (Appendix 1). For vessels with a very rapid turn-around (< 1 day) that are visiting only a single port in New Zealand, the "no action" option may represent a low (but non-negligible) biosecurity risk, as there is a smaller probability that organisms on the vessel will spawn or escape from the biofouling during the time they are in New Zealand than if the vessel remains for longer periods (see Appendix 1).

Establishment of feral populations of a non-indigenous species is a highly stochastic process that is influenced by the reproductive state of organisms in the biofouling at the time of arrival and their ability to spawn and produce viable offspring in New Zealand conditions. As general rules of thumb, the risk is likely to increase with the amount of biofouling present on the vessel and will vary with its geographic origin. Biofouling species from other temperate coastal environments are more likely to be able to establish self-sustaining populations in New Zealand waters than those from predominantly tropical environments (Inglis et al. 2010; Bell et al. 2011).

4.1.3 Resources

No additional resources, personnel, materials or training, are required to implement this option. There are, however, significant potential costs associated with pest control and mitigation of impacts should an incursion occur (see "Strategic Fit" below).

4.1.4 Opportunities/Barriers

There are no major regulatory impediments to implementing this option for any vessel type. However, the 'no action taken' option is unlikely to be supported by the New Zealand public because it does not mitigate biosecurity risk and is not aligned with the Biosecurity Strategy for New Zealand (Tiakina Aotearoa) (Biosecurity Council 2003). It is also not consistent with New Zealand's support of international measures that are being developed to minimize biofouling on international vessels that are under consideration by the IMO.

4.1.5 Strategic Fit

The "no action" option does not provide any mitigation of baseline risk and, therefore, the likelihood of populations establishing within New Zealand will be unchanged. The value of preventing establishment by a non-indigenous marine organism depends on the magnitude of any impacts that it may have on New Zealand's economic, environmental, health, social and cultural values and on the likelihood that those impacts will be realised (MAF Biosecurity New Zealand 2010e). Both factors are difficult to predict and vary greatly among different species. The "Risk Analysis for Vessel Biofouling" conducted by MAF identified 12 broad taxonomic groups that pose a non-negligible risk to New Zealand (Bell et al. 2011). Surveys of international vessels have shown that a diverse range of species within each taxonomic group enter New Zealand as biofouling (Inglis et al. 2010). Many have the potential to alter local environments leading to impacts on ecosystem services. For some, the magnitude of the potential economic and environmental cost means that reducing the probability of incursions will provide significant benefits for New Zealand (MAF Biosecurity New Zealand 2010e).

There have been relatively few attempts to quantify the costs of marine pest incursions in New Zealand. The economic costs of an incursion can be characterized into three components (Nimmo-Bell 2009):

- defensive expenditure – (i.e. the costs of prevention and control of pests);
- production losses (i.e. economic output that is lost through presence of the pest or impacts caused by it); and
- "welfare" losses (i.e. damage to non-market values, including indigenous biodiversity, environmental, cultural and social values).

Expenditures on recent incursions ("defensive costs") by biofouling organisms - the clubbed sea-squirt, *Styela clava*, the Whangamata sea-squirt, *Didemnum vexillum*, and the Mediterranean fanworm, *Sabella spallanzanii* - have been estimated at $2.2 million, $1 million, and $1 million, respectively (Ansell & Coates 2008; MAF Biosecurity New Zealand 2010d). However, these amounts represent only the one-off costs to Central Government and/or industry of initial incursion response and are modest relative to expenditure on incursion response to terrestrial insect pests (Ministry of Health 2004; Minister for Biosecurity 2006; Brockerhoff et al. 2010). They do not include the costs of on-going management of the populations or their impacts. The real costs of control are, therefore, likely to be much greater.

Annual production losses (predominantly to the New Zealand aquaculture industry) from *Styela clava* and *Didemnum vexillum* were estimated at $15 million and $1 million, respectively, based on 2008 values (Nimmo-Bell 2009).

No estimates have been made of the impacts of these or other biofouling species on non-market values. However, a "willingness-to-pay" study has recently been undertaken to assess the dollar value of marginal changes to indigenous marine biodiversity and other attributes of the coastal marine environment associated with a potential incursion by the European green crab (*Carcinus maenas*) (Bell et al. 2008; Bell & Yap 2008). Of the four attributes evaluated in the study - loss of shellfish species, loss of recreational shellfish take, loss of coastal vegetation and inability of children to paddle at the water's edge - loss of indigenous (shellfish) biodiversity was valued most by the respondents. Although focused on a single estuary (Pauatahanui Inlet), the study concluded that if comparable impacts were experienced throughout New Zealand, the expected marginal loss to these non-market values could amount to between $325 million to 600 million (Bell & Yap 2008).

Effects on trade and tourism

The "no action taken" option does not cause any additional inconvenience or cost to operators of the vessel and is, therefore, unlikely to be an impediment to maintenance of trade.

Tourism values may be affected if a harmful organism becomes established and has negative impacts on natural environments that are marketed to domestic and international tourists; for example, when an incursion occurs into a marine environment that is a valued tourism attraction (e.g. marine reserve or dive attraction) or destination (e.g. Kaikoura, Milford Sound, etc).

4.1.6 Net Benefit

Although the "no action taken" option can be implemented readily and without direct cost, it provides no protection to New Zealand's marine environments from non-indigenous marine pests. Establishment by a harmful organism could result in total defensive costs and production losses to aquaculture and fisheries in the order of $10 million to 100 million. Impacts on non-market values (including indigenous biodiversity, environmental, cultural and social values) could be substantially greater. The "no action" option may only be acceptable where the vessel intends spending < 1 day in New Zealand and where there are no feasible alternative options for treatment. Even in these situations, the "no action" option provides less long-term benefit to New Zealand than *Education of vessel masters* (Section 4.2).

4.2 EDUCATION OF VESSEL MASTER THROUGH THE USE OF COMMUNICATIONS MATERIALS

4.2.1 Description of the management option

If a vessel arrives in New Zealand with obvious fouling, the Quarantine Inspector may provide education material to the vessel master on the range of best practice options available for the prevention and mitigation of hull fouling for their vessel type. Depending on the situation, a warning may also be issued with regard to the refusal of entry into New Zealand if the vessel were to return to New Zealand in a similarly fouled condition.

4.2.2 Feasibility

This option can potentially be implemented at any port of entry in New Zealand for any vessel type. However, it provides no immediate mitigation of the biosecurity risk. Because of this, the longer the vessel remains in New Zealand the greater is the risk that the species will spawn or escape from the biofouling and become established (See Appendix 1 and Section 4.1). For vessels with a very rapid turn-around (< 1 day) that are visiting only a single port in New Zealand and which have only small amounts of biofouling, this option may represent a low (but non-negligible) biosecurity risk, as there is a smaller probability that organisms on the vessel will spawn or escape from the biofouling during the short time they are in New Zealand than if the vessel remains for longer periods (see Appendix 1).

Education of the vessel master through use of communication materials may provide some longer-term benefit in mitigating biosecurity risk for return visits by the vessel if there is willingness on the part of the vessel owner/operator to undertake hull cleaning or inspections prior to any return visit to New Zealand (but see "Impacts on Trade and Tourism" below).

The costs to vessel operators of complying with this requirement will depend on the vessel type and their operating costs (See Section 3).

Recreational vessels

For recreational vessels, the requirement for the vessel to be free of biofouling on any future trips to New Zealand is not likely to be a strong disincentive for making a return visit to the country. More than 90% of the recreational vessels sampled in the MAF commissioned research on vessel biofouling had been dry-docked or re-painted in the 18 months prior to their arrival in New Zealand (Inglis et al. 2010). Many indicated that the vessel's hull had been cleaned in the month prior to sailing, often by in-water cleaning (Inglis et al. 2010). Owners of recreational vessels undertake this cleaning to improve their vessel speed over the duration of their voyage and the proposed mandatory requirements may be an extra incentive to clean their boat prior to departure for New Zealand to ensure entry.

Of a sample of 279 international yachts surveyed upon their departure from New Zealand in 2003 - 04, 206 (74%) indicated that they had renewed the antifouling coating on their vessel while in New Zealand. Generally, this occurred towards the end of their residency (on average, after 70 ± 1.6% of the time they would spend in New Zealand; NIWA unpubl. data). It may be possible to create incentives for non-compliant visiting yachts to undertake their maintenance sooner following arrival to New Zealand. However, we are not aware of any information on how frequently recreational vessels make return visits to New Zealand. If return visits comprise a small proportion of entries into New Zealand and/or if the interval between repeat visits is long, then the communications material may have only limited uptake and influence on behaviour.

MAF has undertaken some research on the effectiveness of a communication campaign that advocates cleaning of marine vessels to prevent transport of marine pests (UMR Research Ltd 2006). The campaign was initiated following discovery of the invasive sea-squirt, *Styela clava*. The research showed that engagement of vessel owners at marinas was among the most effective media tools for raising awareness about the need for vessel cleaning and was associated with a higher likelihood that they would take action to clean their boats than other forms of communication (e.g. brochures, posters, direct mail, etc). However, 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 indicated that they 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 it in with regular maintenance or repairs (UMR Research Ltd 2006).

Given the financial costs associated with haul-out and cleaning (Section 4.4), owners of recreational vessels often tend to get several maintenance tasks done while the vessel is out of the water (e.g. re-fit, cleaning, engine servicing, re-painting, etc) and may be reluctant to undertake cleaning outside of their normal schedule of maintenance and repair.

The "clean your boat" communication campaign was based on voluntary compliance with guidelines for cleaning. It did not involve the threat of any penalty for non-compliance. A higher level of uptake may be achieved if non-compliance could result in refusal of entry into New Zealand or the inconvenience and cost of being required to clean the vessel on arrival.

Commercial Vessels

This option is not well-targeted for passenger, fishing or merchant vessels. Decisions about the schedule of maintenance of these larger vessel types are usually made by the vessel lines, owners and/or charterers, in association with their insurers and classification society, rather than by the vessel master. Educational materials would be targeted more effectively at the shipping line companies and agents responsible for chartering vessels and booking port facilities in New Zealand. If the material (and warning) is provided to the companies with sufficient notice before punitive measures are imposed (e.g. 2 - 5 years), then it may be possible for them to act upon the information prior to departing for New Zealand. However, because of the costs involved in cleaning the hulls of large vessels (See Section 4.4), this requirement may be a significant disincentive for some lines to include New Zealand on their forward schedules if New Zealand introduces the requirement for cleaning ahead of other trading nations.

Fishing Vessels

The New Zealand Fishing Industry Association (NZFIA) has already put in place a voluntary code of practice for chartering foreign-owned or sourced fishing vessels that included measures aimed at reducing the risk of heavily fouled vessels entering New Zealand waters (New Zealand Fishing Industry Association 1997). However, it is unclear how much compliance there is with the Code of Practice and, as it considers some level of biofouling acceptable, it is not consistent with the proposed vessel biofouling IHS. As the fishing companies are responsible for the vessel's conduct while it operates in New Zealand they are likely to bear the cost of a disrupted charter and loss of catch if the vessel is refused entry at the border. The existing Code of Practice for managing biofouling on FCVs could be aligned more closely with the proposed IHS.

Passenger vessels

Some cruise lines that market expeditionary cruises to New Zealand's sub-Antarctic Islands and Antarctic territories are already subject to a regime of inspection for biofouling as part of their permit conditions for visiting the islands. This process is regulated by the Department of Conservation under the *Reserves Act 1977* and requires any vessel intending to land passengers on the sub-Antarctic islands to undergo an initial hull inspection at the owner's expense. An entry permit to land on the islands is granted only when no biofouling organisms other than marine biofilm ("slime") are detected on the hull. Presence of more substantial biofouling results in failure of the inspection. The vessel is then either denied a permit or is required to undergo a second, more comprehensive inspection (again at the operator's expense) to determine if any of the organisms in the biofouling pose a biosecurity risk to the islands' marine ecology. While cruise lines have acceded to the inspection regime in order to gain access to the islands, the uncertainty involved in the outcome of the assessment, the lack of suitable options for cleaning the vessels in New Zealand if they fail the inspection, and potential for costly delays or disruptions to the cruise schedule have caused significant concern within the industry.

For other types of cruises that are even more time-constrained with itineraries (e.g. around-the-world cruises) or vessel charter arrangements, there may not be the opportunity for the vessel to undergo additional inspections and cleaning outside its normal schedule of certification surveys.

Merchant vessels

For vessels that are subject to regular freight schedules and which carry cargo for large numbers of clients (e.g. container, general cargo, RoRo and reefer vessels), communications materials about conditions of entry to New Zealand and trade of the vessel are best targeted through the shipping line or agent, rather than the vessel's master. For vessels chartered to carry specific loads (e.g. bulk and tanker charters), engagement should occur through the vessel line and/or major cargo owners. For example, it may be possible for owners of bulk cargo (importers or exporters) to negotiate conditions for vessel hull cleanliness into their charter contracts. However, this is likely to add to the charter costs and will have a flow-on effect on the cost of New Zealand export and import goods. Merchant vessels with very time-constrained schedules (e.g. container lines) or charter arrangements may not have sufficient flexibility in their itineraries to undergo additional inspections and cleaning outside their normal schedule of certification surveys.

4.2.3 Opportunities/Barriers

Recreational vessels

It is unclear how the threat of refusal of entry may be enforced for non-compliant recreational vessels that return to New Zealand. It will not be possible to determine accurately if the vessel is not compliant with the vessel biofouling IHS using pre-arrival information alone. Refusal of entry on arrival poses other challenges because of the sailing time required to get to (and from) New Zealand by these vessels. Yachts surveyed by MAF Quarantine service in 1993 (n = 327 vessels) took an average of 11 days to sail to New Zealand. Several travelling from distant locations took longer than 1 month (Grant & Hyde 1991). Vessels that have recently arrived will need to be re-provisioned (fuel, water and food) before departing and, in some cases, may need to undertake repairs. Fatigue may also pose a hazard to the crew and vessel if they are required to leave New Zealand shortly after arrival. New Zealand has obligations under the *International Convention for the Safety of Life at Sea* (SOLAS), *1974* to ensure that all ships are sufficiently and efficiently manned from a safety point of view.

Article 211(3) of the *United Nations Convention on Law of the Sea* (UNCLOS) allows for Port States to "establish particular requirements for the prevention, reduction and control of pollution of the marine environment as a condition for the entry of foreign vessels into their ports or internal waters". It does not, however, mention biosecurity issues specifically in the definition of pollution. Until recently, the rights of a Port State to refuse entry to a vessel that is in distress, but which may constitute a pollution threat to the marine environment have not been clear. Although it is internationally accepted practice to allow such a vessel to seek a place of refuge near the coast in order to preserve human life, the situation is not regulated by UNCLOS. In 2003, the International Maritime Organization (IMO) clarified the obligations of Port States to provide a safe place of refuge for vessels in distress where the immediate safety of life is not involved (*Guidelines on Places of Refuge for Ships in Need of Assistance* (Resolution A.949(23)). The guidelines recognize that granting access to a place of refuge is a decision that can only be taken on a case-by-case basis and that, in so doing, consideration needs to be given to balancing the interests of the affected ship with those of the marine environment of the Port State.

There is an additional risk that by requiring vessels to be clean prior to entry into New Zealand, owners of recreational vessels will choose to clean their vessel manually, while it is at anchor or on a mooring in the Pacific. Enforcement in New Zealand may, therefore, put greater biosecurity risk from biofouling onto smaller Pacific Island nations.

Passenger and Merchant Vessels

The *Maritime Transport Act 1994* (MTA) enables implementation of New Zealand's obligations under international maritime agreements, including the *United Nations Convention on Law of the Sea* (UNCLOS), the *International Convention for the Prevention of Pollution from Ships* (MARPOL), the *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter* (London Convention) and the *International Convention for the Safety of Life at Sea* (SOLAS). The New Zealand Government is also a signatory to the *Asia/Pacific Memorandum of Understanding on Port State Control* (known as the Tokyo MOU). The Tokyo MOU is the mechanism used to standardize procedures for inspection and control of foreign shipping throughout the Asia/Pacific region. When exercising Port State Control under the Tokyo MOU, the New Zealand Government has an obligation to avoid unduly detaining or delaying a ship.

Section 392 of the MTA describes the matters that must be taken into account when making rules to protect the marine environment from shipping. These include:

a) the need to -
- (i) protect the marine environment;
- (ii) maintain and improve maritime safety;

(ab) whether the proposed rule -
- (iii) assists economic development;
- (iv) improves access and mobility;
- (v) promotes and protects public health;
- (vi) ensures environmental sustainability;

(b) The recommended international practices of the International Maritime Organisation relating to protection of the marine environment;

(c) the costs of implementing measures for which the rule is being proposed;

(d) The risk to the marine environment if the proposed rule is not made;

(e) Such other matters as the Minister or the Director, as the case may be, considers appropriate in the circumstances.

Section 397 of the MTA outlines the powers of the Director of Maritime New Zealand to detain a ship or to prevent it from entering a port or terminal where the Director believes there are clear grounds. These can include where:

(a) There is an existing discharge from the ship of a harmful substance in breach of the MTA or of the Resource Management Act 1991; or

(b) There is likely to be a discharge from the ship of a harmful substance in breach of the MTA or of the Resource Management Act 1991; or

(c) Ships of a particular class are likely to give rise to a discharge of a harmful substance in breach of the MTA or of the Resource Management Act 1991; or

(d) There has not been issued in respect of the ship or the marine protection product, as the case may be, a marine protection document as required by this Act or any regulations or marine protection rules made under the MTA; or

(e) A marine protection document in respect of the ship or marine protection product, as the case may be, has expired; or

(f) Any provision or condition of a marine protection document in respect of the ship, or marine protection product, as the case may be, is not being met; or

(g) The ship or the marine protection product presents an unreasonable threat of harm to the marine environment; or

(h) Any conditions imposed under paragraph (b) or paragraph (d) of subsection (1) of section 397 have not been complied with.

When a ship is detained, Maritime New Zealand must notify the Flag State and the relevant classification society of the detainment. Under the MTA, the costs of detention and any incidental costs related to it are to be met by the owner or operator of the vessel or its representatives. The owner or operator has a right of appeal against a detention decision. Where the decision is found to have been in breach of any marine protection convention and has resulted in undue delay of the vessel, Maritime New Zealand is liable to pay compensation to the owner for any losses resulting from the delay (section 398 (4)).

Article 211(3) of UNCLOS recognises the rights of Port States to:
- Establish particular requirements for the prevention, reduction and control of pollution of the marine environment as a condition for the entry of foreign vessels into their ports or internal waters.

In doing so, Port States have an obligation to:
- give due publicity to such requirements and communicate them to the International Maritime Organization (IMO).

New Zealand, therefore, has an obligation to fore-warn shipping states of any marine protection requirements that may affect entry of foreign vessels into its ports. The potential for refusal of entry on the grounds of biosecurity risk is likely to be subject to this requirement.

International measures being introduced by the IMO to reduce the transport of biofouling by shipping (Annex 26 Resolution MEPC.207(62)) and to reduce greenhouse gas emissions (resolution A.963(23)) mean that shipping companies are under increasing international pressure to develop management plans for their vessels that improve operational efficiency, including fuel consumption and maintenance schedules (Buhaug et al. 2009). Thus, the messages provided by educational materials on biofouling and hull husbandry from New Zealand are likely to align with measures already gaining traction within the shipping industry.

4.2.4 Resources

Some resources will be required to develop suitable communication materials and strategies for different vessel types. Engagement with merchant shipping lines and agents is more likely to be successful if it is done through face-to-face meetings with industry, rather than simply issuance of information packets. It will also be necessary to maintain searchable records on vessels that were issued with a warning so that they may be scrutinized on repeat visits and, where necessary, refused entry.

Most costs of implementing this measure are likely to fall on the vessel owner/operator, through either additional cleaning required outside the normal schedule of maintenance or flow-on costs incurred from non-delivery of cargo and the need to reschedule forward itineraries if refused entry. There are, nevertheless, financial risks to government associated with potential legal challenges to a decision to refuse entry to a vessel or where a vessel has been unduly delayed.

4.2.5 Strategic Fit

4.2.5.1 Effects on trade and tourism

Recreational vessels

The requirement to be free of biofouling on entry to New Zealand may have indirect economic consequences for the maritime services industry within New Zealand. The marine construction and refit industry in Northland, mostly in the Whangarei and Opua Harbours, contributes over $60 million to the regional economy and employs over 450 people (Enterprise Northland 2010). Currently, many of the international recreational vessels that visit New Zealand take advantage of local haul-out facilities to undergo maintenance, cleaning and/or repainting (Table 5; McClary & Nelligan 2001; Inglis et al. 2010; NIWA unpubl. data). The 2002 NIWA survey of departing international vessels estimated that ~ 75% had new antifouling paint applied while they were in New Zealand. Charges for haul-out and cleaning (water-blasting) of a 12 m recreational vessel are around ~ $309 (see Section 4.4). If the vessel is repainted with anti-fouling coatings at the same time, the charges can be up to ~ $3200 (Floerl et al. 2009b). Based on the numbers of international vessels currently arriving in New Zealand each year (Table 3), this could represent a lost opportunity to New Zealand boat yards of up to $1.5 million per annum.

Passenger vessels

Ease of border-crossings (including customs formalities, quarantine agreements, etc.) is just one of a large number of influences on the selection of destinations by cruise lines (King 1999; Papatheodorou 2006). The potential for refusal of entry on arrival to New Zealand may be a significant disincentive for cruise companies to include New Zealand on their itineraries if there is uncertainty around whether or not entry will be granted. The potential flow-on costs to a cruise line from an unanticipated disruption at the border will be substantial, as it could involve refunding part, or all, of the fare for the cruise to passengers, rescheduling of flights, hotels, etc and rescheduling of the vessel itinerary and port access arrangements. Refusal of entry also means an average loss of export revenue to New Zealand in the order of $1 million per vessel (Market Economics Ltd 2008).

Merchant vessels

New Zealand is a small trading nation, in global terms, and accounts for a small proportion of world trade. In total exports and imports, it ranks as the 53rd (out of 120) largest trading nation (Lawrence et al. 2010). New Zealand container volumes account for < 1% of annual global container throughput (New Zealand Shippers' Council 2010). The performance of New Zealand's economy relies heavily on its export sector and, because such a large proportion of our export cargo is carried as sea-freight, the performance of this sector is dependent on our international shipping services (New Zealand Shippers' Council 2010). New Zealand's small size and remoteness from major trading partners limit the availability and quality of its shipping services and it is relatively poorly integrated into global liner shipping networks, being serviced by relatively few shipping lines (Lawrence et al. 2010). Any factors that affect the efficiency, reliability and cost-effectiveness of New Zealand's shipping or which put existing sea-freight services at risk may have flow-on effects to market delivery and export revenues (New Zealand Shippers' Council 2010).

For example, the international container and bulk charter markets are intensely competitive, with high fixed operating costs and relatively slim margins per voyage. In tight market conditions vessel operators may choose to lay up their vessels until the market improves (as happened recently with the global financial crisis; Floerl and Coutts 2009) or to continue to trade below fixed costs (OECD 2003). The costs of compliance with environmental regulations already comprise up to 6.5% of a ship's operating costs (OECD 2003) and, in older vessels, can be up to 15% of the charter rate. Additional measures that affect the profitability of these operations could cause the shipping lines to seek more lucrative markets to operate in or to pass the costs on to New Zealand charterers and cargo owners.

New Zealand currently ranks highly on Global Enabling Trade Indicators for the transparency of its border administration (1st of 125 nations), and for the efficiency of its customs procedures (4th) and clearance processes (16th) (Lawrence et al. 2010). The potential for refusal of entry on arrival to New Zealand could affect these standings and may be a disincentive for some liner and shipping companies to include New Zealand on their itineraries if there is uncertainty around whether or not they will be granted entry. The potential flow-on costs to a merchant vessel from such a disruption at the border will be substantial. Delays can incur costs through unproductive vessel time and the need to reschedule forward itineraries. Depending on the vessel type, these can amount to many tens of thousands of dollars per day (Table 15). Delays also negatively affect the reliability of the services and can result in costs to the cargo owner as a consequence of delayed delivery, additional inventory costs and, in some cases, additional production costs (Notteboom 2006).

For merchant vessels with very time-constrained schedules (e.g. container lines) or charter arrangements, there may not be the opportunity for the vessel to undergo additional inspections and cleaning outside its normal schedule of certification surveys.

4.2.6 Net Benefit

This option will not mitigate the immediate biosecurity threat from the vessel. The longer the vessel remains in New Zealand untreated, the greater is the likelihood that organisms in the biofouling will spawn and become established with the potential for significant harm to environmental, social, economic and cultural values (see Section 4.1). Issuance of a warning against future visits to New Zealand if the vessel is fouled may have some longer-term benefits to biosecurity if there is willingness on the part of the vessel operator to undertake hull cleaning or inspections prior to returning. In this regard, this option is preferable to the "no action taken" option. It is most suited to vessels that intend spending < 1 day in New Zealand and where there are no feasible alternative options for treatment.

The requirement to undertake cleaning prior to return to New Zealand is likely to be most feasible for recreational vessels and foreign chartered fishing vessels (FCVs). It is unclear how many international recreational vessels make return visits to New Zealand and, therefore, what level of uptake there will be of the requirement. Because FCVs come to New Zealand on charter for extended periods (months), the cost of compliance with the directive to have a clean hull on entry may be relatively low compared with the overall revenue that can be gained from the charter (OECD Maritime Transport Committee 2003).

For fishing, passenger and merchant vessels, refusal of entry at the border will have significant financial consequences to the vessel line or charterer and to cargo owners as it will result in the delays of goods to market and additional costs in operations, rescheduling of itineraries and lost production. Because of New Zealand's remoteness and small size, its transport services and connectivity to international markets are already fragile. Any greater uncertainty in the costs to shipping services, such as potential for refusal of entry, may put continued services at risk. For recreational vessels refusal of entry will have significant implications for New Zealand's obligations to the SOLAS convention.

4.3 IN-WATER CLEANING (USING APPROPRIATE TECHNOLOGY TO CAPTURE ALL DEBRIS) OR TREATMENT

In-water cleaning of vessels is strongly discouraged by the current *Australian and New Zealand Environment and Conservation Council Code of Practice for Antifouling and In-water Hull Cleaning and Maintenance 1997* ("ANZECC Code"). The ANZECC Code was developed in response to concerns over the toxic effects of antifouling biocides (particularly tri-butyl tin; TBT) on the marine environment and the potential for in-water cleaning practices to facilitate the establishment of non-indigenous organisms. The ANZECC Code is currently being revised as it is now at variance with the *International Convention on the Control of Harmful Antifouling Systems on Ships* (AFS Convention), which came into force in 2008[2]. It also does not take account of recent developments in antifouling coatings and in-water cleaning technologies (Floerl et al. 2009b). Modern antifouling technologies include coatings that do not contain biocides, but which rely on other mechanisms to keep surfaces free of biofouling. "Foul-release" coatings provide surface characteristics ("non-stick" surfaces) that prevent the attachment of biofouling organisms or cause the attachment to fail when the vessel moves. Fouling-release coatings based on fluorinated polymers and on silicone have been developed and tested, with silicone-based coatings proving the most effective (Floerl et al. 2009b). However, these coatings are less robust than copper based antifouling coatings and are prone to damage by conventional, abrasive in-water hull cleaning methods (Floerl et al. 2009b). In contrast, another type of biocide-free coating, surface treated coatings (STCs) are formulated to be extremely durable. Unlike other coatings, they are designed to be cleaned regularly underwater. Even vigorous cleaning does not damage the surface. Nevertheless, a recent European Commission demonstration project has shown that, although the STC coating "Ecospeed" does not contain biocides, some traces of solvents and softeners, associated with the hardener applied to the surface, are released during cleaning (Wijga et al. 2008). In the concentrations at which they occur, these substances are thought to have no toxic effects on marine life (Wijga et al. 2008).

Proposed revisions to the ANZECC Code recommend that in-water cleaning of fouled international vessels is only acceptable when:

- the antifouling coating is suitable for cleaning;
- the cleaning method does not damage the coating surface;
- discharges from the cleaning will meet local water quality standards; and
- the cleaning method captures and contains all biofouling waste.

Exceptions may be made in emergency situations.

In the case of treatments aimed at killing the biofouling *in situ*, rather than removing it, capture of biofouling waste may not be necessary if it can be demonstrated that the method does not result in release of viable biofouling material.

[2] Australia has ratified the AFS Convention. Although New Zealand has not formally ratified the AFS Convention it has taken action to ban TBT in accordance with the dates set out in it.

In New Zealand, regulation of vessel cleaning activities and pollution in territorial waters is the responsibility of regional government authorities, with national oversight and guidance being provided by the Ministry for the Environment, the provisions of the *Resource Management Act* (1991) and the *New Zealand Coastal Policy Statement*. Outside the 12 nautical mile limit, any cleaning that involves discharge of material will require a dumping permit from Maritime New Zealand under the *Maritime Transport Act 1994*. The Marine Pollution Regulations of the *Resource Management Act* (1991) deem the dumping of organic materials of natural origin (e.g. biofouling) to be a discretionary activity in any regional coastal plan or proposed regional coastal plan thereby requiring a resource consent to be obtained before the material can be dumped. In-water hull-cleaning or discharges associated with it are not restricted coastal activities and a consenting Authority may grant a discharge permit (or coastal permit) if:

- exceptional circumstances justify the granting of the permit; or
- the discharge is of a temporary nature; or
- if the discharge is associated with necessary maintenance work.

Of the 17 acting regional councils in New Zealand, five make specific mention of release of discharges from vessel maintenance into coastal waters in their coastal or regional management plans. Taranaki Regional Council and Environment Southland are the only regional councils that prohibit any form of discharge from vessel cleaning (Floerl et al. 2009b).

The recently-released *New Zealand Coastal Policy Statement 2010* (Department of Conservation 2010) requires operators of ports, marinas and other relevant marine facilities to provide for residues from vessel maintenance to be safely contained and disposed of (Policy 23). Regional authorities are also required to provide, in regional policy statements and plans, mechanisms for the control of activities in or near the coastal marine area that may cause the release or spread of harmful aquatic organisms. Identified risk activities include vessel maintenance (Policy 12; Department of Conservation 2010).

Despite the ANZECC Code, in-water removal of biofouling is a relatively common practice among owners of recreational vessels (Inglis & Floerl 2002; UMR Research Ltd 2006; Floerl et al. 2008; Inglis et al. 2010), but is often undertaken by the owner themselves rather than in an approved facility. Over 66% of the international yachts surveyed in the MAF commissioned research on vessel biofouling (*n* =182) had their hull cleaned manually at some time since the vessel was last painted with antifouling. At least 33% of the sample had cleaned their hull manually in the month prior to entry into New Zealand (Inglis et al. 2010). In contrast, between 4 and 10% of merchant and passenger vessels, respectively, reported in-water cleaning. In these cases, this was most likely to be "spot" cleaning of biofouling in niche areas undertaken using mechanical cleaning methods (see Section 4.3.2).

4.4 REMOVAL BY HAND

Description of the management option

In-water removal of biofouling organisms is often carried out by a diver using hand-tools, such as paint scrapers. This is an effective method for removing some organisms, especially where they are in isolated patches and can be contained with a low risk of viable propagules being released. Squeegees or wiper blades should be used for fouling release coatings to avoid damaging the coating and increased risk of future accumulation of biofouling.

4.4.1 Feasibility

Removal of biofouling by hand is most effective when the organisms occur in small patches (such as in niche areas) and in small abundance or when the vessel has fouling-release coatings on its hull. It will reduce the biosecurity risk relative to the "no action taken" option if the organisms removed can be captured and retained. There is, nevertheless, a risk that some viable organisms or propagules will not be captured during removal. This is particularly a problem for mobile species within the biofouling. Also, because the operator is likely to remove only visible fouling, the microscopic life-stages of biofouling organisms (e.g. new recruits, dormant phases, etc) will not be removed. If the vessel remains in New Zealand for an extended period, these juvenile life-stages may survive and grow to become reproductive adults. For most biofouling organisms this will take longer than 14 days.

While these risks can be reduced by the care taken during cleaning, they cannot be eliminated. Currently, it is not common practice to retain fouling material that is removed by hand during in-water cleaning. In-water removal of biofouling represents a greater biosecurity risk than cleaning in haul-out or dry dock facilities due to greater survival of soft-bodied organisms and the possibility that organisms will spawn or escape during the cleaning (Woods et al. 2007). For vessels visiting more than one port in New Zealand, manual in-water cleaning will reduce the biosecurity risk for subsequent ports relative to leaving the biofouling untreated, but as it will not remove microscopic life-stage of the organisms, some risk remains if the vessel remains in New Zealand for extended periods (> 14 days). Manual cleaning will not eliminate the baseline risk at the port in which cleaning is done unless all viable organisms are able to be removed and retained.

Removal by hand is generally not the preferred method of treatment when the biofouling growth is dense or widespread, as it can be time-consuming and ineffective. If the underwater visibility is poor, not all areas of the hull may be cleaned and not all material removed will be captured. Manual removal is unlikely to be effective for biofouling in recessed areas, such as sea-water inlet pipes and gratings unless these are specifically treated by some other means. In circumstances where there is extensive fouling, manual removal may be used to reduce fouling to levels where other techniques (e.g. rotating brushes) can be used effectively.

The time required to clean a vessel by hand will depend on the amount of biofouling present and the size of the vessel. Where very small amounts of biofouling are present in a few niche areas, it can take just a few hours for divers remove the material by hand, resulting in minimal delay to the vessel. Yachts and vessels < 20 m with moderate cover of biofouling can be cleaned within 1 day (Floerl et al. 2009b). However, where the biofouling is more than minor, cleaning of large (> 150 m) or heavily-fouled vessels by this method is likely to take > 3 days and will result in delays to vessels with rapid port turn-around. In addition to the time required to do the cleaning, a resource consent will be required in most New Zealand ports to undertake the activity. Approved facilities for decontamination will require a generic consent in advance of a vessel being directed to be cleaned. Delays in treatment caused by limited capacity or availability of facilities will increase the biosecurity risk.

4.4.2 Resources

In-water removal of biofouling organisms on large vessels is typically done using mechanical methods (e.g. brushes or water-jets) and would only be done by hand when biofouling is very sparse or concentrated in small areas ("spot cleaning"). It is generally carried out by a diver using tools such as paint scrapers or brushes and can be done at most ports of entry in New Zealand. It is more effective in locations where there is good underwater visibility.

A number of commercial dive companies in New Zealand can offer this service to vessel owners, provided an appropriate consent is obtained. The cost for commercial in-water cleaning for recreational yachts and launches is estimated to be ~ NZ$300 plus GST for a 12 m vessel such as a standard sailing yacht, including cleaning the hull and all niche areas (Floerl et al. 2009b). Golder Associates NZ Ltd (2008) estimated commercial diver fees for manually cleaning a large vessel (> 100 m length) at ~ $4000.

4.4.3 Opportunities/Barriers

The eroding antifouling coatings that are currently used on most vessels that arrive in New Zealand (Inglis et al. 2010) 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. Cleaning with tools such as brushes and scrapers can damage the coating, removing layers of paint and rapidly depleting the biocidal content. Unless care is taken, fine paint particles containing biocides will be released into the surrounding environment during manual cleaning. Softer, fouling-release coatings that do not contain biocides are also prone to damage by abrasion, thereby reducing their effectiveness (Floerl et al. 2009b). In contrast, STC coatings are relatively robust to physical abrasion (Hydrex 2009). The total amount of paint residue released will depend on the coating type and the area of the hull that is cleaned with brushes and scrapers, but is likely to be less than cleaning an equivalent area using abrasive mechanical methods (see Section 3.2). Manual cleaning is also likely to release suspended solids (mostly organic material from the organisms removed) into the surrounding water.

Approved decontamination facilities or contractors will require a resource consent from the regional authority that permits cleaning of a number of vessels per year for the purposes of biosecurity, as and when need arises. Alternatively, the Minister may invoke Section 7A of the Biosecurity Act which allows actions taken to eradicate an organism to be exempt from the provisions of Part 3 of the Resource Management Act 1991 for up to 20 working days if the Minister is satisfied that it is likely that:

a) the organism is not established in New Zealand, the organism is not known to be established in New Zealand, or the organism is established in New Zealand but is restricted to certain parts of New Zealand; and
b) the organism has the potential to cause all or any of significant economic loss, significant adverse effects on human health, or significant environmental loss if it becomes established in New Zealand or if it becomes established throughout New Zealand; and
c) it is in the public interest that action be taken immediately in an attempt to eradicate the organism.

4.4.4 Strategic Fit

The current ANZECC Code discourages in-water cleaning by any method. This code is currently being revised and there are presently no in-water cleaning facilities that have been approved by MAF for the removal of biofouling from non-compliant vessels. The draft guidance document for approval of decontamination facilities for vessel biofouling refers only to recreational vessels and requires removal of the vessel from the water to a contained, land-based facility (MAF Biosecurity New Zealand 2010b). Separate guidance would need to be prepared for in-water decontamination facilities, based on the proposed changes to the ANZECC Code.

4.4.5 Net Benefit

In-water cleaning by manual removal may be used to mitigate risk when biofouling is concentrated in small areas of the vessels hull, such as niche environments. It is generally not feasible to clean the entire hull of large vessels by hand. There is a high risk that not all biofouling will be removed or captured during the cleaning. Large vessels with extensive biofouling would take more than 1 day to clean by this method. 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 MAF approved facilities for in-water decontamination of vessel biofouling. Approved facilities would require resource consent under the Resource Management Act 1991. In-water removal of biofouling by hand is only likely to be effective for vessels with very light or sparse biofouling that is concentrated in small niche areas.

4.5 MECHANICAL IN-WATER CLEANING

4.5.1 Description of the management option

Mechanical in-water cleaning technologies range from water blasters to automated rotating brush systems. Rotating brushes are the most common mechanical cleaning systems and have typically been developed for naval or merchant vessels (including passenger vessels).

Several mechanical brush systems have been developed for cleaning vessel hulls. These range from single brush, hand-held units that are operated by divers to larger hull cleaning machines that have multiple brushes and mechanisms to drive and steer the unit along the hull (Akinfiev et al. 2007; Bohlander 2009).

Single, diver-operated brush units are frequently used by divers to clean fouling from small, niche areas of vessels, such as propellers, gratings and dry-dock support strips. They generally do not capture and treat waste removed from the vessel, but can be fitted with shrouds and suction hoses to achieve this (Hopkins et al. 2008). Cleaning rates using powered hand tools are estimated to be around 0.3 to 0.6 m^2 per minute, depending on the amount and type of fouling, and the experience of the operator (U.S. Army Corps of Engineers 1987b). They are safer to operate than water jet devices and are relatively easy to operate and maintain.

Generally, different types of brushes are used depending on the type of biofouling. Polyethylene brushes may be used to remove slime, algae and soft-bodied organisms, while steel brushes or abrasive discs are used to remove hard calcareous organisms (Akinfiev et al. 2007). Divers can vary the rotating speed of the brush to suit the type of biofouling. Standard operating speeds range from 400 – 700 rpm (Hopkins et al. 2008). Brush bristles and abrasive discs can wear rapidly when used to remove calcareous fouling (U.S. Army Corps of Engineers 1987b).

At least four hull cleaning machines have been developed world-wide: 1) the U.S. Navy Advanced Hull Cleaning System (AHCS), 2) the modified Scamp from Seaward Marine Services, 3) the HISMAR system based in the UK, and 4) CleanROV, a Norwegian system (Bohlander 2009). They are designed to remove light-to-moderate fouling from large, accessible areas of the hull. Only one of the cleaning machines, the AHCS, incorporates a system for capturing and treating water and waste removed from the vessel. It is currently undergoing field testing and is not commercially available (Bohlander 2009). Hull cleaning machines are generally only able to remove biofouling from flat or slightly curved areas such as general hull surfaces. They are not suited for treating cryptic, recessed or structurally complex niche areas (Davidson et al. 2008b; Hopkins et al. 2008). Because the equipment is large and heavy it is typically deployed using a crane or special deck handling equipment. Maximum cleaning rates with these devices are estimated to be ~ 42 m^2 per minute (U.S. Army Corps of Engineers 1987c).

Water jet cleaning systems are currently used in the offshore oil and gas industry to remove fouling from drilling structures. Two-types of system are available: (1) a high-flow system that operates at ~10,000 psi and up to 100 litres per minute, and (2) a smaller, low-flow system that operates at between 3,000 to 10,000 psi and at 11 litres per minute. High-flow systems are a relatively fast and effective method for removing heavy fouling from underwater structures, but no mechanism has been developed to retain the organic and in-organic waste material that is removed by them. Low-flow water-jets provide a fast and effective means for removing light to moderate fouling (U.S. Army Corps of Engineers 1987a). Handling of high-pressure water jets is a potentially hazardous operation (more so than use of brush devices) and requires properly trained operators (U.S. Army Corps of Engineers 1987a). 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 minute can be achieved with high-pressure jets (U.S. Army Corps of Engineers 1987a).

4.5.2 Feasibility

There are currently no commercially available mechanical cleaning systems designed for recreational vessels, although some of the systems could potentially be used for larger recreational vessels such as super yachts that have steel hulls. The abrasive action of brush systems may damage the hull surfaces of recreational vessels that have epoxy and fibreglass hulls (~ 66% of all recreational vessels; Inglis et al. 2010).

In-water removal of biofouling by rotating brush or high-pressure water jet systems is likely to reduce the biosecurity risk relative to the “no action taken” option, but will not eliminate it. Most commercial rotating brush systems and all water jet systems kill and crush a proportion of the organisms they remove, but do not capture all biofouling and paint waste generated by the cleaning process (Bohlander 2009).

The polyethylene brush systems available for use on steel-hulled vessels are most effective on general hull surfaces with low-to-moderate levels of biofouling. They are less effective at removing heavy biofouling that contains large macroalgae, calcareous tubeworms, barnacles and bivalves. More robust cutting heads are available to remove these organisms when there is heavy fouling (Akinfiev et al. 2007). Few existing systems currently capture waste removed during the cleaning. Diver-operated brush units developed in New Zealand as part of a MAF research project were fitted with shrouds and suction hoses designed to capture and contain any paint material or biofouling removed from a hull surface (Hopkins et al. 2008). Around 95 % of the biofouling material that was removed by the brushes was captured by the suction system and retained safely for disposal as landfill when biofouling on the surfaces was relatively light (Hopkins et al. 2008). The material that was not captured included a range of intact organisms that were dislodged by the brush head, dragging hoses, or divers. Heavy fouling was not removed effectively and occasionally blocked the vacuum, potentially damaging filter valves. Use of more robust, cutting brush heads may be more effective at removing larger organisms, but are also likely to be more abrasive to antifouling coatings (Akinfiev et al. 2007). Some variability in the efficacy of the technique was associated with operation of the brush system by different divers and in different environmental conditions (e.g. poor visibility; Hopkins et al. 2008). Because the brushes crush or break organisms during their removal, there is also the risk that gametes or planktonic or brooded larvae may be released during cleaning (Coutts 2002).

Use of mechanical cleaning devices may be restricted on vessels carrying full loads of hazardous, volatile cargo (e.g. petroleum products). The greatest hazard is usually during loading or discharge of cargo. During these times access by divers and mechanical equipment to the vessel is restricted.

4.5.3 Resources

Several commercial dive companies in New Zealand can offer this service to vessel owners, provided an appropriate consent is obtained. At least two prototype rotating brush systems (developed by New Zealand Diving & Salvage and Diver Services Ltd for the MAF research trials on merchant vessels) are available in New Zealand. They are not in regular use and, at present, require at least one day to be mobilised and made operational (Hopkins et al. 2008). The systems are currently based in Auckland and Wellington.

The cost for in-water cleaning using brush systems depends on:

- the number of divers, topside equipment and support personnel required;
- the type of brush system used;
- the size of the vessel;
- the areas targeted for cleaning; and
- the availability of commercial contractors at the port of entry.

Hopkins et al. (2008) provided indicative costs for mobilisation, equipment hire (brush heads, filtration system, pump unit and generator), and operating costs for trained divers (Table 16). Other brush systems that do not have vacuum attachments to capture debris removed during cleaning are lighter and easier to operate by a single diver. They are likely to be cheaper to operate than the vacuum systems.

Table 16: Costs (NZ$) of mobilising and operating the prototype rotating brush systems developed in New Zealand (Hopkins et al. 2008).

Item	Cost ($)
Mobilisation cost	2000
Equipment hire(per day)	600-1000
†Personnel (per day)	3000

†Based on a team of 3 divers

Estimated costs for cleaning niche areas of vessels of different sizes using rotating brushes are provided in Table 17. In New Zealand and Australia, an approximate price for propeller polishing on merchant vessels ranges from NZ$6,500 to 13,000 depending on vessel size (Table 17). 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 (Table 17). The approximate cost of in-water removal of biofouling from all hull and niche areas of a 50 m long ship range from NZ$13,600 – 25,200, 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 (Table 17).

The number of cleaning units required in a port would be determined by the number of vessels that do not comply with the proposed IHS on a daily basis. At this stage, mechanical cleaning is suited only to commercial vessels (i.e. fishing, merchant and passenger vessels). At peak times of the year, 8 to 10 merchant vessels may be in port at the same time in the main ports of entry (principally Auckland, Tauranga, and Lyttelton). During peak cruise season, two to three passenger vessels may be present in the ports of Auckland, Tauranga, Lyttelton, Milford Sound and Dunedin. At the start a fishing season or during crew changeover, 5 or more foreign fishing vessels may be present in the ports of Auckland, Wellington, Nelson or Lyttelton. Currently, > 60% of these vessels have some biofouling on them when they enter New Zealand and would not meet the proposed standard (Inglis et al. 2010). In order to avoid significant delays for vessels with rapid (< 24 h) turn-around, multiple cleaning units would be required in (at least) the ports of Auckland, Tauranga and Lyttelton (Table 9) as well as trained dive teams to operate and service them. At present, therefore, sufficient resources are not available to clean the numbers of vessels that would be non-compliant. Creation of a market for in-water cleaning services could provide an incentive for commercial dive companies to invest in appropriate equipment and training. Further investment is also required in research and development to develop better systems for capturing and containing waste.

4.5.4 Opportunities/Barriers

Contamination risk

The abrasive action of brush systems and high pressure of the water jets can damage some types of antifouling coatings and enhance the rate at which contaminants are released into the surrounding marine environment. Specialised equipment and techniques are required to avoid damaging silicone fouling-release paints (Bohlander 2009).

The MAF research trials on large, steel hulled vessels showed that most large paint particles removed by the brushes could be captured by suction systems, but particles < 60 µm in size (as well as several measuring > 0.5 mm) were released into the surrounding environment resulting in discoloration of the water and potential contamination by biocides (Hopkins et al. 2008). Whether the released material is likely to result in unacceptable water or sediment quality will depend on the amount released per vessel, the number of noncompliant vessels requiring treatment and standards specified in the relevant local coastal plan, regional resource management plan, and consent conditions. Factors likely to influence the nature of any impacts will include:

a) the area of hull treated;
b) the amount of biofouling present;
c) the types of antifouling coating present in the treated area;
d) the hydrodynamic environment where the cleaning takes place;
e) the number of vessels cleaned in the environment;
f) proximity to valued natural environments; and
g) the physical and chemical characteristics of the surrounding sediment and of the residue generated during the cleaning.

Because large vessels will often have a number of paint types on their hull surfaces (Inglis et al. 2010), the risks of contamination may need to be assessed on a case-by-case basis. Nevertheless, there is potential for cumulative effects to occur near facilities that are used regularly or which clean large numbers of vessels. Biocides used within antifouling paints have different environmental fates. Some, such as copper oxides and zinc pyrithione, adsorb readily to suspended particulate matter and accumulate in marine sediments where they can have toxic effects on surrounding organisms (Thomas and Brooks 2010). Others, such as the booster biocides Irgarol 1051 and Diuron, do not persist in sediments but are mostly associated with the dissolved aquatic phase where they have half-lives of up to 350 days. They are highly toxic to phytoplankton and can bioaccumulate in marine macrophytes (Thomas and Brooks 2010).

Costs of delay or disruption

The time taken to clean a vessel using mechanical methods will depend on the size of the vessel, the amount of biofouling on it, and the cleaning system used (Table 17). Small areas of biofouling could be treated within 1 day while the vessel is in port. Although there is no information available on the time required to treat a small craft using a rotating brush cleaning system we anticipate that small vessels with relatively light biofouling could be cleaned in 1 - 2 hours by an experienced commercial operator. Large vessels (> 50 m) with extensive areas of biofouling may take up to several days to clean (Table 17).

International measures to reduce greenhouse gas emissions

International measures being introduced by the IMO to reduce the transport of biofouling by shipping (Annex 26 Resolution MEPC.207(62)) and to reduce greenhouse gas emissions (resolution A.963(23)) mean that shipping companies are under increasing international pressure to develop management plans for their vessels that improve operational efficiency, including fuel consumption and maintenance schedules (Buhaug et al. 2009). Removal of biofouling can result in net power saving to vessels of ~ 5% and improve fuel efficiency of the vessel (Buhaug et al. 2009).

4.5.5 Strategic Fit

The current ANZECC Code discourages in-water cleaning by any method. This code is currently being revised and there are presently no in-water cleaning facilities that have been approved by MAF for the removal of biofouling from non-compliant vessels. The draft guidance document for approval of decontamination facilities for vessel biofouling refers only to recreational vessels and requires removal of the vessel from the water to a contained, land-based facility (MAF Biosecurity New Zealand 2010b). Separate guidance would need to be prepared for in-water decontamination facilities, based on the proposed changes to the ANZECC Code.

4.5.6 Net Benefit

For vessels intending to be in New Zealand longer than 1 day and those visiting more than one port, in-water cleaning using rotating brushes or other mechanical methods is likely to reduce the biosecurity risk relative to the “no action taken” option. The risk of a biofouling organism establishing will increase the longer the vessel remains in port untreated (Appendix 1).

The baseline biosecurity risk for vessels visiting a single port will not be reduced completely by in-water cleaning unless the cleaning system is able to capture and contain viable organisms and their offspring. Available systems for in-water cleaning are generally not designed to capture all waste removed from the vessel so that there is a residual risk to biosecurity and of contamination resulting from the release of organic material, paint residues and antifouling biocides into the marine environment. Conventional ablative or self-polishing antifouling coatings that contain biocides will be abraded by mechanical cleaning, resulting in significant release of biocides and paint residue into the surrounding environment. In locations in which very large or many vessels are cleaned without containment of the waste there is potential for accumulation of contaminants in the surrounding environment. Resource consent would be required to undertake the cleaning in most ports and the discharge would be required to meet local water quality and sediment standards. Vessels with biocide-free antifouling coatings are likely to present negligible risk of chemical contamination to surrounding marine environments provided the cleaning process does not damage the coating surface.

The time needed to mobilise the equipment is likely to result in delays to the schedule of vessels that have expected turn-around times < 1 day. Cleaning of small-sized merchant vessels (< 150 m) with light or moderate biofouling could be done within 1 - 3 days. Large vessels, particularly those with substantial biofouling, may take up to 5 days to clean effectively. Delays that have an impact upon the forward schedule of the vessel will result in costs to the vessel owner and cargo owners.

At present, in water cleaning using mechanical methods is best suited for spot cleaning low densities of biofouling on the hull and niche areas of large fishing or commercial vessels that are likely to be in New Zealand waters for longer than 3 days. Its use in New Zealand is limited by the availability of suitable cleaning systems and divers trained to use them.

Table 17: Estimated costs ($) of available in-water methods for treating biofouling in hull and niche areas of large vessels (> 50 m). The time (in days) required for the treatment is also provided. All prices are in NZ$ and exclude GST. Estimates of time taken to clean a vessel will depend on the size of the team. These estimates are based on a standard commercial team of five (incl. surface support and dive staff) (Floerl et al. 2009).

	In-water Treatment Method											
	Rotating brush systems			Water-blast robot systems			Heat treatment robot system (HST)			Encapsulation		
Vessel Size	**50 m**	**100 m**	**200 m**	**50 m**	**100 m**	**200 m**	**50 m**	**100 m**	**200 m**	**50 m**	**100 m**	**200 m**
General hull areas	8,500	20,000	72,800	18,000	33,800	98,800	Unknown	Unknown	91,600	n/a	n/a	n/a
Niche areas (All)	16,900	20,800	27,300	16,900	20,800	27,300	16,900	20,800	27,300	n/a	n/a	n/a
Sea-chests	5,200	6,500	7,800	5,200	6,500	7,800	5,200	6,500	7,800	n/a	n/a	n/a
Propeller + shaft	6,500	9,750	13,000	6,500	9,750	13,000	6,500	9,750	13,000	n/a	n/a	n/a
Rudder + shaft	5,200	5,200	6,500	5,200	5,200	6,500	5,200	5,200	6,500	n/a	n/a	n/a
Sonar domes and transducers	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	n/a	n/a	n/a
Thrusters	5,200	6,500	7,800	5,200	6,500	7,800	5,200	6,500	7,800	n/a	n/a	n/a
Approx. Total cost: min. - max.	13,600 - 25,300	27,000 – 40,800	85,000 – 101,000	16,000 – 34,800	33,800 – 54,600	105,700 – 127,100	Unknown	Unknown	103,700 – 120,000	3,900[a] - 9,500[b]	15,600[a] – 18,200[b]	30,000[b] – 31,200[a]
No. days required	1 - 2	3	4-5	1	2	3	Unknown	Unknown	3	2-14[c]	3-14[c]	4-14[c]

[a] Using an IMProtector™.

[b] Using plastic silage wrap.

[c] Minimum treatment time assumes use of treatment solutions to accelerate mortality. Maximum treatment time uses "set-n-forget" method.

4.6 ENCAPSULATION

4.6.1 Description of the management option

This method uses an impervious material to cover a vessel hull in order to reduce the water volume surrounding the hull thereby creating toxic conditions for the fouling organisms. The two methods commonly used for encapsulation are based on their re-usability. It is possible to further accelerate the process by the addition of freshwater or chemicals, such as acetic acid or hypochlorite, however, the application of biocides as such may be subject to approval under the HSNO Act.

The encapsulation method works by enclosing a vessel within a sealed, impermeable covering, such as polyethylene plastic, and creating conditions within the enclosed space that are toxic to fouling organisms. The wrapping deprives fouling species 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). Biocides leaching from the vessel's antifouling coatings can also contribute to the mortality. Properly deployed, the wrap is effective at containing biofouling species and their larvae, although care must be taken to ensure that organisms are not dislodged when the wrap is deployed. Encapsulation does not remove the biofouling. Treated organisms are killed and left in-situ.

Mortality within the covering can be accelerated through the addition of biocides. These could include lime, acetic acid, copper sulphate, pool chlorine or sodium hypochlorite (Aquenal 2009). The biocides can be mixed in tanks on shore and circulated using pumps around the enclosed vessel then pumped back to the tanks to reduce chemical use and to keep discharges to a minimum.

One prototype system, the IMProtector™, is designed to pump water from the enclosure into a holding tank so that it can then be treated and tested to ensure it satisfies water quality guidelines (Aquenal 2009). In-line sand filters are used to remove particulate matter likely to carry contaminants. The treated water is then discharged into the marine environment (if it meets local water quality guidelines) or into the local waste water system.

4.6.2 Feasibility

Properly deployed, encapsulation technologies are able to reduce biosecurity risk significantly as they effectively contain the biofouling organisms, including mobile species and any larvae or reproductive propagules that they may shed during treatment. Care must 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. This method is also effective at treating niche areas of a vessel, including through-hull fittings, saltwater systems such as toilets and cooling systems and around propellers and rudder without the need for mechanical disassembly. If the treatment remains in place for long enough (see below), 100% mortality of biofouling organisms can be achieved. Shorter periods of treatment may leave some organisms viable.

The encapsulation method has been tested on recreational vessels (Aquenal 2009) and a few larger vessels, ranging in size from 30 m to over 113 m length, with varying degrees of success (Pannell & Coutts 2007; Golder Associates NZ Ltd 2008). The State Government of

Western Australia is currently undertaking a trial of vessel encapsulation to kill and remove biofouling from large (> 40 m) vessels.

Impermeable plastic silage wrap (125 - 150 µm thick) has been used to encapsulate the vessels with, in some cases, granulated chlorine or 5% acetic acid being added to accelerate mortality of the biofouling (Coutts & Sinner 2004; Pannell & Coutts 2007). Treatment times have ranged from 48 hours (where a treatment solution was added) to 11 days ("Set-n-forget"; Pannell & Coutts 2007; Golder Associates NZ Ltd 2008). For example, 27 vessels ranging in size from 7 to 30 m were treated using encapsulation as part of an eradication programme for the ascidian, *Didemnum vexillum* (Pannell and Coutts 2007). Each vessel was wrapped in a custom-shaped sheet of polyethylene silage cover. Acetic acid was added to the entrapped water between hulls and plastic sheets to create a 5% working concentration of acetic acid. Vessels were left encapsulated for seven days. This treatment was found to be 100% effective for killing *D. vexillum* (Coutts and Forrest 2007; Pannell and Coutts 2007). Upon removal of the sheets, the acetic acid and biofouling material that had dropped off the hulls were left to naturally degrade in the surrounding marine environment. The cost for the encapsulation amounted to approximately $580 per vessel.

In 2007, MAF trialled the encapsulation technique on a 113 m long naval frigate (HMNZS Canterbury), prior to the vessel being sunk as a dive site. Encapsulation of the frigate took 1.5 days and was achieved using 125 µm thick plastic sheeting that was secured against the hull of the vessel. During the encapsulation process the plastic sheet tore in several places and had to be repaired by divers. The sheet was left in place for a period of 11 days (including the installation time), after which a 30 m long tear in the material was discovered, caused by contact with the adjacent wharf (Golder Associates 2008). Diver observations indicated that mortality of biofouling organisms had commenced in those parts of the vessel that were not affected by damage to the plastic sheeting. Although not successful, the study indicated that encapsulation may reduce biosecurity risk on large vessels if an effective seal can be achieved by the encapsulation material (Golder Associates 2008).

Aquenal (2009) claim that treatment of small vessels (< 20 m) by encapsulation will take 1 hour when a biocidal solution is added or 24 hours when none is used, "depending on (the) biofouling species present and local conditions". There are, however, no publicly available data to show the levels of mortality achieved for different biofouling taxa using these protocols. Organisms such as barnacles and bivalves can be quite resistant to short-term exposure to unfavourable conditions and may require considerably longer periods of treatment. For example, the Northern Territory Department of Primary Industry, Fisheries and Mines' Marine Pest Management Unit uses an encapsulation sheath and liquid sodium hypochlorite solution (NaOCl, 12.5% w/v, at a concentration of 200 – 400 ppm) to treat vessels fouled with invasive bivalves (i.e. the black-striped mussel, *Mytilopsis sallei*, and Asian green mussel, *Perna viridis*). The sheath and chemical treatment are kept in place for 36 to 48 hours for each vessel. Similarly, protocols developed during the black-striped mussel incursion in Darwin used an encapsulation sheath and treatment with 5% (by volume) detergent solution or copper sulphate at a concentration of 4 mg/l for 48 hours (Ferguson 2000).

Preliminary results of the IMProtector™ treatment on yachts indicate that when no treatment solutions are used, mortality of all biofouling taxa can take 4 to 5 days (Floerl et al. 2009b).

4.6.3 Resources

Recreational vessels

There are currently no commercially produced encapsulation systems being used in New Zealand for recreational vessels. Prototype systems have been developed in Australia for 15 m and 18 m vessels (Aquenal 2009) and a commercially produced system (the "Bottom-liner") is available in the USA. As the materials used to construct encapsulation systems are readily available, it seems likely that units could be produced relatively quickly for use in New Zealand if there is demand. Operation of an encapsulation treatment system in a port of entry will require resource consent, covering management of waste and treated discharge. It is likely that the consent would cover operation of the facility and would not be required for individual vessels.

Aquenal (2009) have estimated the installation and operating costs associated with four configurations of the IMProtector™ suitable for vessels < 15 m length (Table 18):

- a mobile system that can be deployed at any safe mooring;
- a system installed permanently in a dedicated marina berth;
- a system installed permanently on a dedicated pile mooring; and
- a system installed permanently on a dedicated swing mooring.

Aquenal (2009) claims that an infested vessel can be enclosed within 15 minutes using a system installed permanently in a quarantine berth. A mobile system would take 30 to 60 minutes to deploy depending on how it is stored and used. Both systems can be installed from the shore or boat and do not require the use of divers (Aquenal 2009).

Floerl et al. (2009) estimated that the cost to treat a single, 12 m vessel using encapsulation was likely to be between NZ$390 to 650. For busy ports of entry, Aquenal (2009) recommended a permanently installed system on a dedicated marina berth. Mobile systems may be appropriate for ports of entry that receive relatively few arriving vessels.

Table 18: Installation and operating costs ($) of four configurations of the IMProtector™ (Aquenal 2009).

	System	Installation cost ($)	Operating cost ($) per annum†
1)	Mobile	11,724	47,345
2)	Canister installed in a permanent marina berth	55,922	64,145
3)	Canister installed on a pile mooring	112,323	16,090
4)	Canister installed on a swing mooring	119,476	61,805

†Excludes costs of the treatment solutions and consumables used per yacht

The numbers of units required will depend on the number of vessels that require treatment and the time taken to treat each effectively. Eighty-five percent of the recreational vessels surveyed in the MAF commissioned research on vessel biofouling had some biofouling organisms on them (i.e. more than a slime layer; Inglis et al. 2010) and, during peak periods, up to 25 vessels arrive in Opua per day. Without other measures to reduce the incidence of biofouling, between 7 to 20 vessels could require treatment per day in Opua during peak times (Table 3). Estimated treatment times of between 48 hours to 5 days would require the presence of multiple encapsulation systems (perhaps as many as 30) in Opua during peak times. Other main ports of entry may be able to cope with substantially fewer units. Although Aquenal (2009) suggest treatment times as short as 2 hours, there is considerable uncertainty about the efficacy of encapsulation over such short periods.

Commercial vessels

There are currently no commercially available encapsulation systems for vessels larger than 20 m length. Aquenal (2009) suggest that the maximum size of their prototype encapsulation system, IMProtector, is about 100 to 120 m long by 30 to 35 m wide. Such a system would be suitable for the smallest of the fishing, passenger and merchant vessels (i.e. small feeders, bulk carriers or tankers) that visit New Zealand. The materials and the expertise to undertake encapsulation of a large vessel are present in New Zealand, but there is only limited experience and capacity. In the absence of an off-the-shelf system, encapsulation would require deployment of readily available materials, such as polyethylene silage plastic for a single use. It is unlikely that these materials could be re-used after they had been deployed on a vessel. Deployment of an encapsulation treatment system in a port of entry will require resource consent that covers management of waste and treated discharge from within the wrap.

The estimated costs of encapsulation for large vessels are presented in Table 17. The prices given include only the cost of the wrap and an estimate of the time required for treatment. A more detailed account of the costs involved in deploying and removing plastic wrap from the 113 m frigate, HMNZS Canterbury is given in Table 19. These figures apply to use of the "set-n-forget" technique.

Table 20 provides an indication of the costs of different chemicals that may be used to accelerate mortality during encapsulation and the approximate volumes needed for vessels of different sizes. Marine service charges for berthage of vessels of different sizes during the treatment are presented in (Table 15). For a 100 m vessel, the berthage charges alone may amount to $12,600 for a 14 day deployment of the encapsulation sheath. Other indirect costs associated with the detention and delay of merchant vessels are outlined in Section 3.

Table 19: Estimated costs ($) for the full encapsulation of a large vessel (Golder Associates NZ Ltd 2008).

Item	Quantity	Rate ($)	Cost ($)
Polyethylene silage plastic (15 x 300 m; 125 µm)	1	3250	3250
Silage tape (144 mm wide; 30 m roll)	24	8.50	204
Underwater PVC tape (40 mm wide)	19	4	76
Rope (8 mm x 110 m length; superfilm; 3 strand)	16	39	624
Air fills	23	12	287
Boat hire	3.5	250	875
Crane hire (for wrap removal)	1	950	950
Skip hire (for wrap and rope disposal)	1	290	290
Tug hire (for buffer removal and replacement)	2	320	640
Crew mobilisation*	3 days	1500	4500
Crew demobilisation*	3 days	1500	4500
Disbursements (including additional equipment, telecoms)*	1	1000	1000
Total Cost			$17 196

Note: * denotes approximate labour costs and associated disbursements for a local dive team

Table 20: Estimated volume (L) and cost ($) of chemicals needed to treat vessels of different sizes using the encapsulation method.

		Estimated volume to treat (L)			Cost ($)		
		Vessel length			Vessel length		
Treatment Chemical	Cost ($)	50 m	100 m	200 m	50 m	100 m	200 m
Vinegar (10% by volume)	$378.00 per 200 L	1300	5700	8800	2,457	10,773	16,632
Pool chlorine (8g per L)	$79.00 per 10 kg	1300	5700	8800	79	79	79
Sodium Hypochlorite (2% by volume)	$52.00 per 20 L	1300	5700	8800	422	1852	2860
Lime (30g per L)	$3.40 per 40 kg bag	1300	5700	8800	3.40	6.80	10.20

4.6.4 Opportunities/Barriers

Contaminant risk

Any water discharged directly from the encapsulation systems 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.

If the 'set-n-forget' method is used with filtration of discharged water, the overall contamination risk using this system is potentially lower than other in-water cleaning methods and will be similar to the contamination risk associated with haul-out facilities which use similar filtration systems to capture contaminants and organic waste. The volumes of water that would need to be treated for large vessels would require substantially larger pumping systems than those described by Aquenal (2009) for yachts and the wrap would need to be more watertight than has been achieved to date to avoid release of contaminants to the marine environment. At present, the specifications for such systems and their feasibility have not been determined.

No information is currently available on the effect that encapsulation, with or without treatment solutions, has on the antifouling coatings of vessels. Changes in the pH or availability of metal ions within the seawater enclosed by the unit, associated with decomposition products or treatment solutions, may cause damage to the antifouling coating or to the hull surface. Sulphur deposits formed during the decay of biofouling may also interact with the antifouling coatings, reducing their performance. Further research is needed on the effects of encapsulation techniques on different hull surfaces and coatings to ensure that the technique does not have any unanticipated effects on the vessels.

Costs of delay or disruption

Encapsulation techniques are likely to cause delays to the schedules of vessels with turnaround times < 4 days. Depending on the size of the vessel, it may take divers between 1 to 2 days to deploy and secure the encapsulation sheet once it has been prepared (Denny 2007; Pannell & Coutts 2007). For example, it took divers 1.5 days to wrap the 113 m length decommissioned frigate, HMS Canterbury, an extra two days to repair and consolidate the wrapping (i.e. add belly ropes, tape sections etc.) and 11 days for the treatment to take place (Denny 2007). Longer treatment periods are expected for encapsulation to achieve 100% mortality of biofouling using the 'set-n-forget' method (Denny 2007).

Owners of international recreational vessels and cruise passengers typically live aboard the vessel while they are in New Zealand. Being required to anchor for extended periods away from the attractions they came to New Zealand to see and away from facilities such as sewerage, potable water and shops for extended periods would be viewed as a serious inconvenience.

International measures to reduce greenhouse gas emissions

International measures being introduced by the IMO to reduce the transport of biofouling by shipping (Annex 26 Resolution MEPC.207(62)) and to reduce greenhouse gas emissions (resolution A.963(23)) mean that shipping companies are under increasing international pressure to develop management plans for their vessels that improve operational efficiency, including fuel consumption and maintenance schedules (Buhaug et al. 2009). Removal of biofouling can result in net power saving to vessels of ~ 5% and improve fuel efficiency of the vessel (Buhaug et al. 2009). Because biofouling is not removed from the hull by encapsulation, there is likely to be little improvement in the performance of the vessel following treatment compared to other management options.

4.6.5 Strategic Fit

Even if suitable facilities and resources are present for encapsulation treatment, the major barrier to use of this technique is the time that the vessel would be required to remain immobile for the treatment to be effective. Up to 14 days at anchor may be required for effective treatment using the 'set-n-forget' method. Shorter treatment times could be used when some biosecurity risk is deemed acceptable and the expectation is that not all biofouling organisms will be killed or when biocides or fresh water are used to accelerate mortality.

For vessels with expected turnaround times of > 14 days, the combination of encapsulation and freshwater treatment while at an established mooring or marina berth may be an acceptable option. Encapsulation prior to treatment with freshwater would lessen the risk of biofouling organisms releasing offspring in response to lowered salinity.

Encapsulation techniques are likely to cause significant delays to the schedules of vessels with turnaround times of < 4 days (i.e. most merchant and passenger vessels and some recreational vessels). Such delays would present a significant impediment to trade and tourism.

4.6.6 Net Benefit

Encapsulation has potential as a relatively low cost, method to contain and treat biofouling organisms on small (< 20 m length) and decommissioned vessels. Prototype systems have been shown to reduce biosecurity risk relative to the untreated situation. However, it is still a technology in development. For non-compliant recreational vessels, the net benefit of encapsulation is likely to be smaller than the option of removing the vessel from the water and waterblasting in a contained facility. Although the encapsulation sheaths can be applied relatively easily to a small vessel (< 20 m), the cost of treatment is estimated to be of the same order as haul-out and water-blasting of the vessel. The latter can be done quickly and relatively cheaply in the main centres for recreational boating: Auckland, Bay of Islands and

Whangarei. Encapsulation may be a viable option for small vessels in ports where there is no available decontamination facility (i.e. accredited haul-out or in-water cleaning facilities). Multiple encapsulation facilities would be required in busy ports of first entry during peak periods of arrival.

There are some uncertainties regarding the minimum time required for encapsulation to be effective (with or without addition of biocides) and its effect on antifouling coatings. Vessels with anticipated turn-around times > 14 days in port may be able to use encapsulation without the need to use biocides in the treatment. For other vessels, the time required for deployment and treatment (Golder Associates NZ Ltd 2008) would result in substantial direct and indirect financial cost to the vessel operator through disruption to the vessel's forward schedule unless biocides are used to accelerate mortality of biofouling. Commercial encapsulation services are not currently available in New Zealand ports of entry, but could be developed if there is demand for them. They have not been demonstrated to be successful for treating biofouling on large (> 100 m length) vessels. Water discharged from the encapsulation sheath is likely to have a high biological oxygen demand and, potentially, high concentrations of contaminants that will require treatment.

4.7 HEAT TREATMENT

4.7.1 Description of the management option

The only reported use of heat treatment on a vessel hull was for the removal of an Undaria pinnatifida infestation on a sunken vessel. Heat treatment applications eliminating newly settled fouling organisms to prevent the establishment of complex fouling assemblages are currently being developed.

At least two proto-type systems have been developed to treat biofouling on vessels using encapsulated heat (thermal shock). Both systems were designed for use on steel-hulled vessels. In New Zealand, a 'hot water box' system was developed by dive company New Zealand Dive & Salvage Pty Ltd to treat general hull areas of a fishing trawler that sank in shallow coastal waters off New Zealand's Chatham Islands (Wotton et al. 2004). It consisted of a wooden box with a single open side that was placed onto the vessel's hull. Foam seals on the sides created a closed area inside the box that contained heating elements. The elements were powered by a generator on an attending support vessel and heated the water inside the box up to a temperature of 70°C for 15 minutes. The hull area covered by the box was then treated for 10 minutes. Divers used a flame torch to treat the curved and recessed areas of the hull where the boxes were not practical.

A similar system (Hull Surface Treatment – HST) is being commercialized in Australia by Commercial Diving Services Pty Ltd (http://www.commercialdiving.com.au/hull_surface_treatment_hst.html). It consists of a 'thermal applicator' (current prototype dimensions are 2.5 x 1.5 m) that is lowered from a support vessel and that attaches to the hull of the treated vessel using strong magnets. The hull areas and biofouling enclosed within the thermal applicator are then exposed to water of 70°C temperature supplied from a diesel-powered boiler unit on the support vessel above. The exposure time is approximately 4 seconds, which is sufficient to kill algal growth and recently-settled barnacles. The thermal applicator automatically changes position using a system of roller wheels and is operated from the support vessel without the need for divers. Commercial Diving Services Pty Ltd is also developing a lightweight, portable and diver-operated device (HST Niche applicator - HSTNA) that uses the same technology to treat niche and recessed areas of vessels that cannot be treated using the HST.

Neither system of heat treatment captures and retains biofouling. Treated organisms are killed and left in-situ.

Heat has also been used to manage biofouling in sea-chests of merchant vessels. Magnetic covers are be used to seal the external gratings of the sea-chest and hot water is either injected into the cavity from within the vessel or outside it.

4.7.2 Feasibility

There are currently no prototypes of heat-treatment systems available for recreational vessels.

Both the 'hot box' and HST 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. However, it is likely that the systems will provide some mitigation of biosecurity risks for these groups. Large, mobile organisms within the biofouling will not be treated effectively. The developers of the HST claim that the diver-operated version, the HSTNA, is capable of killing even structurally complex biofouling assemblages. Independent tests of these units are not yet available.

4.7.3 Resources

There are no commercial heat treatment systems currently available in New Zealand and there is limited international experience of their use and efficacy.

The 'hot-box' system was purpose-built by New Zealand Dive & Salvage Pty Ltd for treatment of the Seafresh wreck. It is the only system of its kind in New Zealand. Complete treatment of the sunken 40 m trawler cost NZ$380,000 (Wotton et al. 2004).

It took 4 weeks to treat the sunken 40 m vessel Seafresh 1 using the 'hot box' system (Wotton et al. 2004). This is largely because treatment of each section of hull enclosed by the box took ~ 25 minutes. The box had to be repositioned manually by divers 311 times to ensure the entire hull was treated. Some of the time taken in the procedure may also have been associated with managing the nitrogen loading of divers operating the unit at 20 m depth.

The HST system is not present in New Zealand. In Australia, Commercial Diving Services Pty Ltd offers HST treatment on a contractual basis that involves two HST treatments per annum. During the marketing and launching phase of this technology, they charged approximately AUS$145,000 (NZ$193,000) per year for a vessel of 200 m length, entailing two complete treatments six months apart (Floerl et al. 2009b). Estimates of the costs to treat niche areas of vessels using the HST technology and a > 200 m vessel are provided in Table 17.

Commercial Diving Services Pty Ltd reported that they treated a 247 m passenger vessel, the Pacific Dawn, in 16 hours (one 8–hour shift on each side) using a single HST unit. The estimated Total Wetted Surface Area (TWSA) of the Pacific Dawn is ~ 8,306 m^2. It is possible that, using two HST units simultaneously treatment of a 200 m vessel could occur within 12 hours.

4.7.4 Opportunities/Barriers

The developers of the HST claim it has no effect on the antifouling coatings of merchant vessels, but it is unclear if heat treatment would harm the coatings used by recreational vessels or the fibreglass and resin surfaces of their hulls. Some coating manufacturers are in the process of excluding heat-treated coating surfaces from warranty (Akzo Nobel, pers. comm.)

Commercial Diving Services Pty Ltd commissioned an independent test of water quality in the vicinity of a vessel being treated by the HST. This study concluded that the treatment had no observable effects on the temperature, pH, and concentrations of zinc, copper, total suspended solids, total nitrogen, total phosphorous in the surrounding harbour water (http://www.commercialdiving.com.au/HST_Support.pdf). However, this result needs to be verified for a range of different types of antifouling systems.

4.7.5 Strategic Fit

Because it is intended to treat marine slime, the HST system may have some utility in grooming vessels to ensure they remain compliant with the proposed IHS for vessel biofouling. It is not, however, a useful mechanism for treating non-compliant vessels. Because biofouling is not removed from the hull by heat treatment, there is likely to be little improvement in the performance of the vessel following treatment compared to other management options. A corollary is that heat treatment with not result in the reduction in fuel consumption or greenhouse gas emissions that are expected from treatments that improve hull surface smoothness by removing biofouling.

4.7.6 Net Benefit

The HST system shows some promise for dock-side grooming of biofouling on steel-hulled vessels. However, as it was designed to treat marine slime (biofilm) and algal biofouling its efficacy on more developed biofouling assemblages is unproven. Further research and development is needed to determine its efficacy and effect on antifouling coatings.

Heat treatment is not a viable option for treating biofouling on recreational vessels as its effect on the integrity of fibreglass and epoxy surfaces is unknown.

4.8 FRESHWATER TREATMENT

4.8.1 Description of the management option

Immersion in freshwater has been suggested as a biofouling treatment by, for example, the navigation of a vessel into a freshwater river environment or into a purpose-built freshwater lock.

There are two published examples of the use of navigation into freshwater environments as a treatment for marine biofouling. Both involve decommissioned merchant or naval vessels and both studies report some (but not total) reduction in biosecurity risk. Brock et al. (1999) described movement of the warship USS Missouri into the Columbia River in Oregon for 9 days prior to it being moved to Hawaii. Following the period of freshwater immersion and subsequent voyage to Hawaii, 90% of the hull was clear of fouling organisms. Eleven species were found alive, four of which were likely to be from the original biofouling assemblage.

Notably, one of these species, the mussel *Mytilus galloprovincialis*, subsequently spawned and established a feral population in Pearl Harbour (Apte et al. 2000).

Davidson et al. (2008a) examined the biofouling assemblages on two heavily fouled, decommissioned vessels before and after they passed through the Panama Canal. Despite being in freshwater environments in the canal for around 7 days, nine of the 22 taxa recorded before the voyage were present in the follow-up surveys, with several still present and alive in substantial numbers.

4.8.2 Feasibility

The efficacy of freshwater immersion will depend on the species present in the biofouling and the duration of immersion. Some life stages of invertebrates and macroalgae are killed effectively by immersion periods of < 24 hours (Coutts & Forrest 2005; Forrest & Blakemore 2006). Resistant life stages and species may take considerably longer to kill using this method. For example, Forrest & Blakemore (2006) showed that the gametophytes of the Asian kelp *Undaria pinnatifida* can survive freshwater immersion for up to 2 days. Juvenile mussels (*Perna canaliculus*) survived for longer than 5 days immersion.

The examples provided above (Brock et al. 1999; Davidson et al. 2008a) suggest that vessels may need to remain moored in freshwater for periods of between 7 to 14 days to ensure all marine biofouling is killed. Moreover, there may be an additional biosecurity risk associated with movement into freshwaters as, for some marine species, rapid changes in water temperature and salinity can trigger spawning.

There are relatively few rivers in New Zealand that are deep enough to allow keeled vessels or large craft to navigate into fully freshwater environments. Recreational vessels entering New Zealand typically draw between 0.9 to 7 m (Mean ± S.D. = 2.1 ± 0.9) of water (Inglis et al. 2010), requiring channels that are ~ 2 m to 8 m deep at Lowest Astronomical Tide (LAT). Those rivers that are navigable are generally not near main ports of entry for recreational or commercial vessels.

Table 21 below provides a summary of rivers and freshwater environments near each of the ports of entry into New Zealand.

The ports of Greymouth and Westport, on the west coast of the South Island are New Zealand's only river ports capable of accommodating vessels > 30 m. The Port of Greymouth, located at the entrance to the Grey River, can accommodate vessels up to 106 m length that have a draft of 4.8 to 6 m. The Port of Westport is located in the Buller River. It can accommodate vessels up to 16,000 DWT, with a maximum length of 131 m and draft of 5 m. Both ports have difficult entrance bars that require pilotage and/or which must be negotiated during favourable tide and weather conditions. Both are very small ports with limited berth space. The requirement for a large vessel to remain in freshwater for > 7 days for treatment would occupy much of the berth space available.

4.8.3 Resources

Currently, very few international passenger, fishing, merchant or recreational vessels visit the ports of Greymouth or Westport. Diversion of ships to these locations would require extra voyage time (and associated operating costs) and extra port costs (e.g. berthage, tug and pilot fees, etc) associated with keeping the vessels in port for > 7 days. Delays of this duration would entail significant time-charter costs and potential loss of revenue. The ports are also likely to suffer significant disruption to normal business if the berth space was fully occupied by a large vessel for more than 1 week. For passenger vessels, there would also be major logistical difficulties in dealing with large numbers of passengers and crew, who would need to come ashore or to leave the cruise for the time the vessel is detained for treatment. Importantly, there is not berth capacity in either river system to allow treatment of multiple large (> 100 m) vessels simultaneously, as may be required given current rates of likely non-compliance with the proposed IHS for vessel biofouling (Inglis et al. 2010).

For recreational vessels, this option is only likely to be feasible if significant investment is made into capital and maintenance dredging to deepen channels into suitable freshwater environments in Northland (e.g. the Waitangi River in the Bay of Islands) and to provide facilities for mooring. Alternatively, investment would be needed into purpose-built infrastructure, such as freshwater locks. A third option is to use freshwater in combination with encapsulation to accelerate the death of biofouling organisms. Facilities in the Bay of Islands would need to be capable of treating 7 to 20 vessels per day during peak periods of arrival. The long immersion times required to mitigate biosecurity risk using this method (estimated at between 1 - 2 weeks) would require facilities that could accommodate a large number of vessels simultaneously.

Table 21: Rivers and other freshwater environments near major ports of entry for vessels in New Zealand.

Port of entry	Description of nearby estuarine and freshwater environments
Opua/Bay of Islands	Waikare Inlet near Opua is navigable by small vessels past Marriott Island, but is estuarine.
	A freshwater basin at Haruru Falls in the Waitangi River can only be reached by vessels with a shallow draft as the channel is 0.1 m deep at LAT.
Whangarei	The Hatea River in Whangarei Harbour is navigable by small vessels to the Town Basin Marina. Waters in the marina are brackish, but contain heavy infestations of the non-indigenous estuarine species *Ficopomatus enigmaticus* and *Musculista senhousia* (Inglis et al. 2006).
Auckland	In Waitemata Harbour, keeled vessels can navigate and moor into the upper reaches near Herald Island and Lucas Creek and at West Park Marina in Henderson Creek. These areas are all tidal and estuarine. The non-indigenous fanworm, *Sabella spallanzanii* is known to be present in each of these locations.
	The Tamaki River is navigable for small vessels to Seaside Park, Mt Wellington, but is tidal and contains infestations of the non-indigenous estuarine species *Ficopomatus enigmaticus* and *Musculista senhousia*.
Gulf Harbour	The nearest rivers are the Weiti and Okura Rivers. The Okura River is within the Long Bay-Okura Marine Reserve, while the Weiti River is immediately adjacent. The Okura River is not navigable by keeled boats (entrance to the channel is 0.1 m LAT). There are pile and swing moorings in Weiti River up to Duck Creek, but the entire reach is estuarine.
Tauranga	The Town Reach of the Port of Tauranga is navigable to the SH2 road bridge, but is still estuarine at that point.
Gisborne	The Turanganui River is navigable to the Kaiti Basin, but further passage is blocked to masted vessels by the Gladstone Road and Ormond Road bridges. At this point the waters are brackish.
Napier	Access into the Taipo Stream is blocked by the Pandora Street Bridge. At this point the stream is estuarine.
New Plymouth	There are no navigable rivers near the Port of New Plymouth.
Wellington	The Hutt River is navigable to vessels only with a shallow draft (0.4 m LAT) to the Waione Street bridge. At this point, waters are still estuarine.
Nelson	There are no major rivers navigable by small craft near the Port of Nelson.
Picton/Havelock	There are no rivers navigable by small craft near the Port of Picton.
	In Pelorus Sound, the Kaituna River is navigable by small vessels to Havelock. Waters in the Havelock marina are brackish.
Greymouth	The Port of Greymouth, located at the entrance to the Grey River can accommodate vessels up to 106 m length that have a draft of 4.8 to 6 m. The Grey River has a difficult entrance bar that must be negotiated during favourable tide and weather conditions.
Westport	The Port of Westport is located in the Buller River. It can accommodate vessels up to 16,000 DWT, with a maximum length of 131 m and draft of 5 m. The Buller River has a difficult entrance bar that must be negotiated during favourable tide and weather conditions.
Lyttelton	There are no major rivers navigable by small craft near the Port of Lyttelton.
Timaru	There are no major rivers navigable by small craft near the Port of Timaru.
Dunedin	There are no major rivers navigable by small craft near the Port of Otago.
Bluff	There are no major rivers navigable by small craft near the Port of Bluff.

4.8.4 Opportunities/Barriers

Because owners and crew of international vessels typically live aboard the vessel while they are in New Zealand, being required to anchor in inland waters away from the attractions they came to New Zealand to see and away from facilities such as sewerage, potable water and shops for extended periods would be seen as a serious inconvenience.

4.8.5 Strategic Fit

Even if suitable facilities or environments could be identified for freshwater treatment, the major barrier to use of this technique is the time that the vessel would be required to remain in freshwater for the treatment to be effective. Existing research suggests that > 7 days at anchor may be required. Nevertheless, there is the added risk that some organisms may spawn when exposed to waters of reduced salinity or temperature. For most passenger, merchant and fishing vessels, delays of 7 days or longer for treatment would cause serious disruption to schedules and would have significant potential impacts on trade and tourism.

Because biofouling is not removed from the hull by freshwater treatment there is likely to be little improvement in the performance of the vessel following treatment compared to other management options. A corollary is that freshwater treatment with not result in the reduction in fuel consumption or greenhouse gas emissions that are expected from treatments that improve hull surface smoothness by removing biofouling.

4.8.6 Net Benefit

Freshwater treatment is unlikely to be feasible for most fishing, passenger and merchant vessels entering New Zealand waters. The only river ports suitable are very small and have difficult access for larger vessels. They could only accommodate the very smallest of these vessels that visit New Zealand. The time required to reach these environments and for freshwater treatment to be effective (> 7 days) will cause severe disruption to the schedules of the vessels, resulting in substantial direct and indirect costs to the operators and cargo holders and, potentially, the ports.

Navigation into fresh- or brackish waters by recreational vessels is likely to result in the mortality of a large proportion of the biofouling after several days, but runs the additional risk of stimulating spawning behaviour in organisms under stress. There are few first ports of entry for recreational vessels that have navigable rivers nearby so that treatment by freshwater immersion is not a feasible option.

4.9 HAUL OUT AND CLEANING

4.9.1 Description of the management option

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.

Patent slips or marine railways use a wheeled cradle to winch the vessel from the water up the incline of a slipway. Maintenance of the vessel is then undertaken on the slipway or nearby.

Synchrolifts and travel-lifts consist of a submerged cradle, onto which the vessel is manoeuvred. The cradle is then lifted vertically out of the water by a set of hoists or winches and can be moved with the boat to an area nearby for maintenance. The largest synchrolifts are capable of lifting vessels of up to 100,000 tonnes, but they are more commonly used for vessels between 30 and 25,000 tonnes. The largest synchrolift in New Zealand (in Bluff) is capable of lifting vessels of up to 1,000 tonnes (Table 23).

When vessels are hauled out for cleaning on land 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 (travelifts). Coutts et al. (2010) used biofouling on settlement plates to simulate the effects of removing vessels from the water. Between 8 to 20% of mobile organisms can be lost from the fouled surfaces when they are removed from the water. This risk can be mitigated by enclosing the vessel in a protective shield before it is removed from the water (Ferguson 2000; Aquenal 2009). However, treatments that use manual scraping, water-blasting or desiccation cannot then be applied while the enclosure remains in place.

Large vessels are more commonly removed from the water using a dry-dock. These are narrow basins that can be flooded to allow a vessel to be floated in. The basin is then drained of water to provide a dry working platform. A permanent dry dock basin is usually referred to as a graving dock. Floating dry-docks are moveable pontoons that have buoyancy chambers that can be flooded to sink the pontoon, allowing the vessel to enter it. The chambers are then emptied of water to refloat the basin with the vessel on board. Because dry docking facilities are limited and costly, large vessels generally dry dock only as frequently as needed or when they are required to do so by their insurers or classification societies. Dry-dock facilities must usually be booked well in advance, as they are often in high demand. Without advance booking, delays of weeks are not uncommon whilst suitable facilities become available.

A summary of marina and shipyard facilities in New Zealand that can haul-out vessels up to 1,800 tonnes is presented in Table 22. Facilities available for vessels > 1,800 tonnes are presented in Table 23. Larger vessels, up to 345 m length and 100,000 DWT can be handled in facilities in Australia (Table 23). There is, however, high demand for these facilities.

MAF has recently developed draft requirements for facilities involved in cleaning the hulls of recreational vessels that are not compliant with the proposed IHS for vessel biofouling (MAF Biosecurity New Zealand 2010b) The requirements include guidance on the physical design of decontamination (cleaning) areas, the cleaning operations and collection and disposal of wastes. Approved facilities must be able to demonstrate that they can contain all solid and liquid waste removed during the cleaning. Waste water generated during hull cleaning is not to be discharged to the sea or a waterway (that is, streams that lead to the sea), unless it meets a discharge standard specified in the draft requirements.

Table 22: Boatyards and vessel cleaning facilities in New Zealand. Data are sourced from a combination of McClary & Nelligan (2001) and internet searches of local boating and business directories.

Location	Facility name	Capacity of hardstand	Lifting method	Max weight (tonnes)	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	No data
Russell	Russell Marine Slipway Rails	2	Slipway	150	24	No data
Tutukaka	Tutukaka Marina	No data	Slipway	40	20	No data
Whangarei	Norsand Ltd	70	Slipway	70		11
	Dockland 5 Services	60	Travelift	70	No data	No data
	New Zealand Yachts International	No data	Slipway	800	60	20
	Riverside Drive Marina	30	Travelift	40	No data	No data
	Ship Repair NZ Ltd	No data	Slipway	40	No data	No data
	International Yacht Services Ltd	No data	No data	No data	No data	No data
	H&H Marine & Engineering Services	No data	Slipways x 2	70	No data	No data
Warkworth	Sandspit Yacht Club	No data	Slipway	10	12.5	No data
	Lees Boatbuilders	No data	Slipways x 2	No data	No data	No data
	Mahurangi Marina	No data	Stroplift	23	No data	No data
	Robertson Boats Ltd	5,000 m² hardstand + 3 sheds	Travelift	80		8.5
Gulf Harbour	Gulf Harbour Marina	15,000 m² hardstand + 800 m² shed	Travelift x 2	110	30	7.9
Auckland	Halfmoon Bay Marina (Auckland Maritime Foundation)	100	Travelift	35	18.29	No data
	Babcock Fitzroy Ltd/HMNZ Naval Base	4	Synchrolift	200	34	8.5
	Babcock Fitzroy Ltd/HMNZ Naval Base	No data	Slipway	100	No data	No data
	Westpark Marina	"extensive hardstand area"	Travelift	35	15.24	No data
	Westpark Marina		Travelift	75	24.39	No data
	Devonport Yacht Club	hardstand (capacity or area not specified)	Slipway	10	No data	No data
	Pine Harbour Marina	No data	Travelift	50	28	No data

Location	Facility name	Capacity of hardstand	Lifting method	Max weight (tonnes)	Max length (m)	Max. Beam (m)
	Orams Marine (Westhaven)	6,000 m² hardstand	Travelift	60	25	6
	Orams Marine (Westhaven)	sheds (4 vessels), temporary covered facility (1 vessel)	Slipway	600	55	No data
	Orams Marine (Westhaven)	310 vessels	Boat dry stack	No data	12	No data
	Pier 21 (Westhaven)	190 vessels	Boat dry stack	No data	9.2	No data
	Pier 21 (Westhaven)	30 vessels	Travelift	50	25	No data
	Floating Dock Services (Westhaven)	1	Floating dock	20	15	No data
	Titan Marine Engineering Ltd (Westhaven)	1?	Slipway	1500	80	No data
	Viaduct Harbour Marine Village	"unrestricted open-air hardstand and covered hardstand for vessels up to 10 metres high"	Travelift	35	No data	5.8
	McMullen Wing & Wing Ltd	9,290 m² enclosed work space + "extensive outdoor storage space" + shed for 50 m vessel	Travelift	70	No data	6.8
	McMullen Wing & Wing Ltd		Slipway	300	50	No data
	Salthouse Boatbuilders	2 large sheds for vessels up to 30 m	Slipways x 3	Up to 80	30	No data
Tauranga	Refit NZ Ltd	12 vessels	Slipway	600	65	No data
	Tauranga Bridge Marina	No data	Travelift	35	20	No data
	Tauranga Marina Society	50 vessels	Travelift	35	20	No data
	Hutcheson Boatbuilders Ltd	20 vessels	Slipway	90	25	No data
Coromandel	Whitianga Marina	15 vessels	Travelift	35	No data	No data
Gisborne	Eastport Marina	No data	Travelift	No data	No data	No data
	Port Gisborne	No data	Slipway	400	No data	35
Napier	Napier Sailing Club		Slipways x 3	20	12	No data
	Charter Boats Ltd	3 vessels	Slipways x 3	100 10	30 12	No data
	Napier Slip Way Ltd	No data	Slipways x 2	100 15	No data	No data
Wanganui	Q-West Boatbuilders	3 worksheds	Slipway	200	No data	No data
Taranaki	Port Taranaki	No data	Synchrolift	150	No data	No data
	Fitzroy Yachts	No data	Slipway	No data	No data	No data
Wellington	Seaview Marina	35 vessels	Travelift	50	20m	No data
	Chaffers Marina	None	Travelift	40	18	5.9
	Clyde Quay Boat Harbour/Royal Nicholson	No data	Slipway	No data	No data	No data

Location	Facility name	Capacity of hardstand	Lifting method	Max weight (tonnes)	Max length (m)	Max. Beam (m)
	Yacht Club					
	Evans Bay Marina	No data	Slipway	18	14	No data
Kapiti Coast	Mana Marina	No data	Travelift	30	20	No data
Havelock	Havelock Slipway	5 vessels	Slipways x 3	100	No data	No data
Picton	Carey's Boatyard	2 vessels	Slipways x 2	120	No data	No data
	Waikawa Marina (Franklin Boatyard)	3,555 m^2 hardstand + 2 refit sheds	Travelift	35	No data	5.2
Nelson	Dickson Marine (Refits) Ltd	1,672 m² hardstand	Travelift	50	24.4	6
	Calwell Slipway/Nelson Ship Repair Group	not specified	Slipways x 2	1800 100	65 30	No data
Lyttelton	Lyttelton Port Company	1 or 2	Dry dock	600	120	No data
	Lyttelton Port Company	No data	Slipway	130	30	No data
	Stark Bros.	1	Slipway	30	20	No data
	Naval Point Yacht Club	23 cradles	Ramp + tractor	15	No data	2.2 (draft)
Christchurch	Christchurch Yacht Club	No data	Slipways x 3	20	15	No data
Greymouth	Port of Greymouth	No data	Slipway	150	No data	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	No data	No data
	Otago Yacht Club	hardstand (capacity not specified)	Slipway	12	12	No data
	Miller and Tunnage Boat Builders	4	Slipways x 4	100	30	No data
Dunedin	Otago Harbour Recreational Boating Club	No data	Ramp	20	10	No data
Bluff	Southport NZ Ltd	12	Synchrolift	1050	45	No data
	Ocean Beach Slip	4	Slipway	30	18	No data

Table 23: Shipyard facilities in New Zealand capable of haul-out of vessels > 1,800 DWT and facilities in Australia capable of haul-out of vessels > 10,000 DWT (The Worldwide Shipyards 2010 database, http://www.ship2yard.com/index.php).

		Graving dry dock capacity			Floating dry dock capacity		
Shipyard	**Location**	**DWT**	**Length (m)**	**Beam (m)**	**Lift (t)**	**Length (m)**	**Beam (m)**
New Zealand ship yards							
Ship Repair NZ Ltd	Whangarei	2,000	(Slipway)	No data			
Babcock Fitzroy Ltd /(Calliope dry dock)	Auckland	140,000	181.4	24.3			
Lyttelton dry dock	Lyttelton	No data	137	14			
Australian ship yards							
ADL Services Group	NSW	100,000	345.5	41.6	1,000	63	12.9
AUSTAL	WA		120.6	24.7			
Forgacs Cairncross Dockyard	QLD	85,000	263.2	33.5	15,000	200	29
Forgacs Dockyard Newcastle	NSW	No data	256	32.5	45,000	200	29.5
Forgacs Ship Repair, Revesby	NSW	85,000	263	33.5	45,000	200	29.5
Forgacs Shipyard	NSW	10,000	150	No data			
Geraldton Port Authority	WA	75,000	No data	No data			
INCAT Marketing Pty Ltd	TAS	No data	150	30			

Methods for treatment of biofouling once the vessel has been removed from the water include scraping, waterblasting and desiccation.

4.10 SCRAPING

Hand tools, ranging from a scraper to a shovel, can be effective at removing large aggregations of biofouling from a vessel hull. If the vessel is not being re-painted while on the hard-stand then care must be taken to avoid abrading the antifouling coatings during the cleaning. In particular, abrasive cleaning will damage antifouling systems that use fouling-release coatings. These are best cleaned with soft cloths or squeegees.

4.10.1 Feasibility

Removal of biofouling by scraping is likely to be effective only when the organisms occur in small patches and in small abundance. Manual removal of biofouling in haul-out facilities is likely to be more effective than manual removal in-water because the operator can see where the biofouling is more easily and is less likely to overlook fouled areas. As long as the haul-out facility has suitable measures in place to prevent waste removed from the vessel from being returned to the sea, manual removal on land is likely to contain all waste removed from the vessel.

Manual scraping is not effective for biofouling in recessed areas, such as sea-water inlet pipes, seachests and gratings, unless particular care is taken to treat these areas. Also, because the operator is likely to remove only visible fouling, the microscopic life-stages of biofouling organisms (e.g. new recruits, dormant phases, etc) will not be removed. These may survive to reach adult stages if the vessel is returned to the water soon after cleaning.

4.10.2 Resources

Recreational vessels

There are haul-out facilities for recreational vessels present in all major ports of entry (Table 22). They vary in the mode of haul-out used (i.e. slipway, travel-lift, etc), the size of vessels that can be accommodated, and the amount of hardstand area available. Not all of these facilities will currently meet the MAF draft requirements for hull cleaning facilities for international recreational vessels. Many have particular areas where biofouling is removed from the vessels and will not allow cleaning to occur in general hard-stand areas.

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 by scraping (Floerl et al. 2009b). Cleaning of large, heavily-fouled vessels may take longer than 1 day. Key influences on the time required for treatment will be the capacity of the haul-out facility and demand for their services, including hard-stand storage areas. Between October and December, when most recreational vessels arrive in New Zealand from overseas, demand for haul-out and decontamination facilities in Opua and Whangarei, as a result of quarantine measures, may mean delays of >1 day. The longer the vessel remains in the water untreated, the greater is the risk of establishment by a non-indigenous species.

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 Table 24. For small vessels (< 9.1 m length), haul-out and storage for a day can range from $120 to 250, depending on the facility. For larger vessels (20 - 22 m length), the comparable rates are $620 to 1481 per day. The large variation in rates may mean that vessel owners would seek to choose the service they use if they are directed by quarantine inspectors to have their vessel cleaned and if the owners are required to cover the costs of cleaning.

Table 24: Mean, minimum and maximum charges ($) for haul out, wash and storage of vessels of different sizes.†

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

Fishing vessels

There are 15 shipyard facilities in New Zealand capable of handling fishing vessels > 30 m length (Table 22 and Table 23). These are distributed throughout the country, with eight in the North Island and seven in the South Island.

The Code of Practice adopted by the New Zealand Fishing lndustry Association for Foreign Chartered Vessels (FCVs) contained provisions that allowed the New Zealand charterer to request the ship owner to take appropriate action to have the hull cleaned if it was found that the biofouling was:

- beyond that which would be considered normal or acceptable; or
- if the hull contains species which are known to be toxic, or contains species which are likely to be a threat to the New Zealand coastal environment or to aquaculture (New Zealand Fishing Industry Association 1997).

If an assurance is not provided by the vessel owner that the vessel is substantially free of biofouling when it arrives in New Zealand, the New Zealand charterer has the right to require a hull inspection at the ship-owner's cost upon the vessel's first arrival in a New Zealand port. Where there is evidence that the vessel contains substantive biofouling, the ship owner will be requested to take appropriate action to have the vessel cleaned. The cleaning of any ship's hull "*shall be undertaken in such a manner that no foreign plant or animal life is deposited into the coastal marine area. Any material removed from the hull of a foreign vessel shall be deposited in a land-based refuse site in a manner which prevents its subsequent entry into coastal waters* (New Zealand Fishing Industry Association 1997)."

Each year, a number of the FCVs take advantage of haul-out facilities in New Zealand during lay-up periods to undergo repair and re-painting. There is, however, high demand for their use and space in the facilities must usually be booked well in advance. The dry docks at Lyttelton and Auckland are capable of accommodating two vessels of 40 – 50 m length simultaneously. If demand is greater than this the vessels will have to wait, untreated, until the facility becomes available.

The costs associated with slippage or dry-docking and removal of biofouling depend on the size of the vessel (Table 25). The total cost can be up to $38,000 for vessels > 5000 GRT in addition to up to 3.5 days of lost revenue when biofouling is removed by waterblasting (Table 26). 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 (New Zealand Fishing Industry Association 1997). Cleaning done by hand (i.e. scraping) is likely to take substantially longer unless macrofouling is very sparse. Actual dry-docking periods can be longer than these estimates because repairs or refits are done while the vessel is out of the water. The time required for treatment will also depend on demand for the haul-out facilities and their availability.

Table 25: Approximate cost ($) of shore-based biofouling removal on medium-sized commercial vessels at slipway facilities. Also presented is the estimated time (in days) required for the treatment. Prices are in NZ$ and exclude GST (Floerl et al. 2009b).

Vessel size:	25-m vessel	40-m vessel	60-m vessel
Removal from and return into water	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)

Table 26: Charges ($) for dry-dock hire and services for large ships (up to 5000 tonnes) at the Lyttelton Port Company's dry-dock in New Zealand. Also presented is the estimated time (in days) required for the treatment. Prices are in NZ$ and exclude GST (Floerl et al. 2009b).

Vessel size:	500 gross tonnes	1000 gross tonnes	5000 gross tonnes
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)

Passenger and Merchant Vessels

The large size of most passenger (see Section 3) and merchant vessels (Section 3) that enter New Zealand means that few can be hauled from the water or dry-docked in New Zealand and most would need to be directed to facilities in Australia (2 - 3 days voyage), or elsewhere overseas, for treatment.

Only three New Zealand shipyard facilities are capable of handling vessels > 1800 DWT (Table 23) and there is high demand for their use. For example, a MAF request to have the decommissioned naval frigate NZHMS Canterbury dry-docked for biosecurity reasons could not be fulfilled because of a waiting list of several months for the Auckland facility (Denny 2007). Vessels up to 345 m length and 100,000 DWT can be handled in facilities in Australia (Table 23). There is, however, also high demand for these facilities.

The costs associated with dry-docking and removal of biofouling depends on the size of the vessel (Table 26, Table 27). The total cost can be up to NZ$264,000 (ships over 200 m), plus 1 to 3 days of lost revenue when the cleaning is done by water blasting (Table 27). Cleaning done by hand (i.e. scraping) is likely to take substantially longer unless macrofouling is very sparse. Actual dry-docking periods are often longer than these estimates because repairs or refits are done while a vessel is out of the water.

Table 27: Approximate charges ($) for dry-dock hire and hull cleaning in Australia. Also presented are estimates of the time (in days) required for the treatment. Prices are in NZ$ and exclude GST (Floerl et al. 2009b).

	Vessels approx. 100 m length	Time required (days)	Vessels ≥200 m length	Time required (days)
Dry-dock hire	27,000	2	81,000	3
Access equipment	41,000		58,000	
Cleaning (water blast)	24,000		88,000	
Sea chest cleaning	3,000		3,000	
Waste removal	20,000		34,000	
Total cost for biofouling removal	116,000	2	264,000	3

4.10.3 Opportunities/Barriers

Cleaning a vessel in a MAF approved decontamination facility should pose no additional pollution risk to the marine environment since a condition of approval is that all waste should be contained and any waste water must be treated to meet specified standards before it can be discharged to marine waters. However, as the MAF standard for hull cleaning facilities is still in draft form there is some uncertainty over which cleaning facilities will be able to meet the standard in the short-term and, therefore, what the overall capacity to service non-compliant vessels is within major ports of entry.

4.10.4 Strategic Fit

For large vessels, haul-out and cleaning is expensive and can take several days to complete. This does not include time spent in lay-up waiting for the limited facilities in New Zealand to become available. During peak periods of vessel arrival, the limited availability of haul-out facilities may exacerbate biosecurity risk by requiring vessels to wait untreated in port until facilities are available. Merchant and passenger vessels with short-turn around times are likely to experience significant disruption to their schedules that will have flow-on costs to the operators and impacts on trade and tourism.

4.10.5 Net Benefit

Recreational vessels

Haul-out facilities are available throughout New Zealand and regularly undertake cleaning of biofouling from small vessels. Many are equipped to retain and dispose of waste removed from the vessels to minimise risks to marine biosecurity and pollution. Provided there is sufficient capacity within the facility, vessels with light-to-moderate fouling may be cleaned and returned to the water in < 1 day. Scraping of biofouling can be done cheaply by the vessel owner or facility operator, but will be effective only for visible macrofouling. Juvenile and cryptic organisms may be overlooked.

During peak periods of arrival of recreational vessels (October to December) demand for haul-out of non-compliant vessels for treatment is likely to exceed the capacity of facilities in the main first ports of call (i.e. Opua, Whangarei, and Auckland). During these periods it may be necessary to use alternative methods to treat fouled vessels (e.g. manual in-water cleaning or encapsulation) or to require the vessel to proceed directly to another port where haul-out facilities are available.

Fishing vessels

Haul-out and cleaning is a feasible option for most fishing vessels that enter New Zealand. Many FCVs already use some of these facilities while on charter in New Zealand. Haul-out facilities capable of accommodating FCVs are distributed throughout both the North and South Islands. However, the existing facilities are in high demand and advance booking is usually required. Substantial delays may be incurred (and associated increased biosecurity risk) if facilities are not available immediately, as may happen during peak periods of arrival prior to the fishing season. The costs for haul-out of large vessels are large and, once the vessel has been removed from the water, cleaning by high pressure water-blasting is usually more cost-effective than hand scraping because of the greater efficacy of the water blast and shorter cleaning times required.

Passenger and merchant vessels

Haul-out and cleaning is not a feasible option for most passenger and merchant vessels that enter New Zealand as the shipyard facilities currently available are generally not capable of handling very large vessels and are in high demand. Haul-out will require either substantial delays, whilst the New Zealand facilities become available (vessels < 118 m length) or diversion to a facility overseas. The long voyage times and costs involved in complying with an instruction to be cleaned in a haul-out facility are likely to be significant disincentives for vessels to include New Zealand in their itineraries. Large vessels that intend staying in New Zealand for longer than a few days and which are not compliant with the proposed IHS will require in-water cleaning or may be refused entry to mitigate the biosecurity risk.

4.11 WATERBLASTING

4.11.1 Description of the management option

Waterblasting is a common technique for removing biofouling from the vessel prior to further maintenance or replacement of the antifouling protection. Waterblasting entails spraying water under pressure (2,000 psi or greater) from a lance, often with the water exiting in a triangular, scraper-like pattern.

High-pressure water-blasting is usually done once the vessel is on a slipway, dry dock or floating dock. The power of the water blast may be varied depending on the type of antifouling coating on the hull (e.g. silicone based paints require gentler treatment), but is usually up to 8,000 psi (Floerl et al. 2009b).

4.11.2 Feasibility

Water-blasting is a more efficient way of removing large biofouling organisms from vessel hulls than manual removal. It may not be effective for biofouling in recessed areas, such as sea-water inlet pipes and gratings, unless particular care is taken to treat these areas. These niche areas may be treated using other methods, such as flushing with detergents or chemicals (e.g. bleach) or, in the case of sea-chests, through removal of the outer grating and water-blasting the inside of the chest. Also, care should be taken to treat the entire hull to ensure that microscopic stages of biofouling species are removed. These may survive to reach adult stages if the vessel is returned to the water soon after cleaning. As with other haul-out methods, some biofouling organisms may be lost or dislodged during removal of the vessel from the water.

4.11.3 Resources

See Section 4.4.1.

4.11.4 Opportunities/Barriers

See Section 4.4.1.

4.11.5 Strategic Fit

See Section 4.4.1.

4.11.6 Net Benefit

See Section 4.4.1.

4.12 DESICCATION

4.12.1 Description of the management option

Desiccation, or air-drying, is a technique where the vessel is removed from the water and left on a hard stand until all biofouling has died. Although desiccation is most commonly used to treat biofouling on aquaculture and fishing equipment, this technique has been recognised as having potential for controlling vessel biofouling.

The rate at which biofouling organisms die when exposed to air varies with local environmental conditions, such as temperature, humidity, rainfall, and direct sunlight, and with the amount of biofouling present. Large aggregations of biofouling can retain moisture that allows small organisms to survive within them. While some soft-bodied organisms die relatively quickly when removed from the water, other biofouling species are able to remain viable for many days. For example, gametophytes of the non-indigenous macroalga, *Undaria pinnatifida* can remain viable for 2 – 3 days at 10°C (Forrest & Blakemore 2006). The non-indigenous tunicate, *Styela clava*, can survive aerial exposure for up to 6 days, depending on ambient temperature (Coutts & Forrest 2005). More resistant species, such as barnacles and bivalves, can remain viable for much longer periods. For example, the bivalves *Mytilus galloprovincialis* and *Perna perna* are capable of surviving continuous aerial exposure for > 7 days with almost no mortality (Branch & Steffani 2004). Other, less tolerant species may survive within dense biofouling assemblages that retain moisture. Hilliard et al. (2006) recommended that the minimum period for air drying of biofouling on vessels should be 21 days, with any reduction requiring expert analysis of the biofouling on a case-by-case basis.

There are additional biosecurity risks if the vessel is returned to the water without the desiccated organisms being removed. Many macroalgae, including *U. pinnatifida*, are induced to release spores following periods of desiccation (Thompson 2004). Thus, if the dried algae are returned to the water with the vessel there is a high risk of establishment.

4.12.2 Feasibility

Air-drying of biofouling is only feasible for vessels with an expected turnaround time in port > 21 days. Shorter periods of aerial exposure will not completely mitigate the biosecurity risk (Hilliard et al. 2006).

Commercial vessels

Removal of fouling by desiccation is not a feasible treatment option for large vessels (> 30 m). Most haul-out facilities do not have sufficient hard-stand area to allow a large vessel to remain out of the water for such extended periods of time. Only three shipyard facilities in New Zealand are capable of handling large vessels (Table 23) and there is high demand for their use. The daily charges for remaining in dry-dock or slipway would be prohibitive for a period of 21 days (> $54,000). Most merchant and passenger vessels that enter New Zealand are too large for haul-out facilities in New Zealand and would need to be directed to facilities in Australia, or elsewhere, for treatment.

4.12.3 Resources

Recreational vessels

Haul-out facilities are present in all major ports of entry for recreational vessels (Table 22). They vary in the mode of haul-out used (i.e. travel-lift vs. slipway vs. dry-dock), the size of vessels that can be accommodated, and the amount of hardstand area available. In some ports of entry there is limited capacity for hard-stand and much of this area may already be occupied by storage of domestic vessels.

Charges for haul-out and storage of vessels vary among facilities and with the size of vessel. An indicative summary of charges is presented in Table 24. For the 21 day period on hard-stand recommended by Hilliard et al. (2006), vessel owners could expect to pay between $500 and 872 for a small (9.1 m length) vessel and between $2,422 and 4,461 for a large vessel (22 m length). This does not include costs for removal of the biofouling prior to returning the vessel to the water. These costs are much greater than those associated with haul-out and cleaning by water-blasting, which can be done with much shorter turnaround times (< 1 day).

Commercial vessels

Charges for haul-out of vessels vary among facilities and with the size of vessel. An indicative summary of charges is presented in Table 25, Table 26 and Table 27. The very large costs involved with the dry-docking of a merchant vessel and lost revenue associated with having the vessel inactive for such extended periods mean that desiccation is not a viable option. Keeping a passenger or merchant vessel in a haul-out facility for > 14 days would entail substantial direct cost to the vessel operator (in the order of $280,000 for a 200 m vessel) and significant lost revenue (in the order of $560,000 in charter time, see Section 3). This does not include costs for removal of the biofouling prior to returning the vessel to the water or for rescheduling of the vessel's passengers, cargo, crew and forward charters.

4.12.4 Opportunities/Barriers

There is no additional aquatic contamination risk associated with air-drying of biofouling on a hard-stand.

It is often not possible for owners or crew of vessels to live aboard them while they are in hard-stand storage for extended periods of time. This means that, in addition to the costs of renting the hard-stand space, alternative accommodation may have to be found for the period of treatment.

Because biofouling is not removed from the hull by desiccation, there is likely to be little improvement in the performance of the vessel following treatment compared to other management options. Moreover, return of desiccated macroalgae and other resistant organisms to seawater may result in release of spores and offspring thereby exacerbating biosecurity risk.

4.12.5 Strategic Fit

Haul-out and treatment by desiccation will require delays > 21 days. The large costs and inconvenience involved in complying with an instruction to be treated in this manner will be a significant disincentive for these vessels to include New Zealand on their schedules. The costs and extended delays caused by the treatment would have significant impacts on New Zealand maritime trade and tourism.

4.12.6 Net Benefit

This option offers reasonable mitigation of biosecurity risk for recreational vessels with expected turnaround periods > 14 days, provided the biofouling material is removed from the hull before the vessel is returned to the water. However, the same outcome could be achieved much quicker and more cheaply by water-blasting the vessel in an approved containment facility. There is likely to be a substantial inconvenience and cost to owners/operators of the vessels related to the time required for desiccation to be effective.

Haul-out and treatment by desiccation is not a feasible option for passenger, merchant and fishing vessels that enter New Zealand as the shipyard facilities currently available are generally not capable of handling very large vessels and are in high demand. Haul-out and treatment by desiccation will require delays in excess of 21 days. The large costs involved in complying with an instruction to be treated in this manner will be a significant disincentive for these vessels to include New Zealand on their schedules.

4.13 REFUSAL OF ENTRY INTO NEW ZEALAND

4.13.1 Description of the management option

Depending on the situation, a Quarantine Inspector may prohibit a vessel from entering/docking in New Zealand waters until the hull has been sufficiently treated to ensure there is no biosecurity risk.

4.13.2 Feasibility

This option can potentially be implemented at any port of entry in New Zealand for any vessel type.

Refusal of entry at the border will reduce the biosecurity risk from vessels scheduled to remain in New Zealand for longer than 1 day, but will not mitigate the smaller risk from vessels with short turn-around times (< 1 day) unless entry is refused before the vessel has entered New Zealand’s territorial waters (e.g. based on assessment of submitted pre-arrival information such as the Master's Declaration for Full Biosecurity Clearance or similar). Refusal of entry may provide some longer-term benefit in mitigating biosecurity risk for return visits if the costs incurred by the operator of the vessel through refusal of entry provide an incentive for them to ensure that the vessel is clean prior to its next voyage to New Zealand.

Refusal of entry to a New Zealand port may not mitigate the biosecurity risk completely for small vessels. Recreational vessels that are refused entry to ports on the New Zealand mainland may seek refuge on more isolated parts of the northern coastline (e.g. Rangaunu Harbour, Parengarenga Harbour), including New Zealand's offshore islands, before departing for other countries. Unless refusal of entry is absolute, some may also be tempted to clean their vessels manually in these locations before seeking re-entry to the New Zealand mainland. This may particularly be a problem for New Zealand registered yachts that are returning from overseas and for yachts involved in race events to New Zealand that depart from the islands.

The New Zealand Fishing Industry Association (NZFIA) has already put in place a voluntary code of practice for chartering foreign-owned or sourced fishing vessels that included measures aimed at reducing the risk of heavily fouled vessels entering New Zealand waters (New Zealand Fishing Industry Association 1997). However, it is not clear how much compliance there is with the Code and, as it considers some level of biofouling acceptable, the Code of Practice is not consistent with the proposed IHS for vessel biofouling. Provision to meet the IHS may be able to be included as part of the charter agreement between the New Zealand charterer and the vessel owner as an incentive for vessels to be clean prior to entry into New Zealand and/or as part of the conditions of vessel registration with MAF (formerly MFish). However, even in this situation, non-compliance and refusal of entry would have financial consequences for the charterer through lost revenue and fishing time. The preferred option of the fishing industry is implicit in their Code of Practice, which requires the owners of non-compliant vessels to take appropriate action to have the vessel cleaned in New Zealand if it is found to have unacceptable levels of biofouling on entry (New Zealand Fishing Industry Association 1997).

For large vessels (> 50 m) that have substantial biofouling (i.e. more than spot fouling in niche areas) and which are scheduled to be in New Zealand for > 1 day, refusal of entry may be the only viable option to mitigate the biosecurity risk. The longer the vessel remains in New Zealand untreated and the greater biomass of fouling organisms it contains on its hull, the greater is the risk of establishment of a non-indigenous species. While it is difficult to quantify the likelihood of establishment and the consequences for any particular species, the impacts on core environmental, social, economic and cultural values can be substantial (See Section 4.1). Since the costs of refusal of entry can also be great (see below and Section 3), these risks will need to be evaluated on a case-by-case basis taking into consideration the amount of biofouling, duration of stay in New Zealand waters and costs of refusal of entry. Vessels with only small patches of biofouling and short-term stays (1 to 3 days) may best be issued with education materials and a warning against returning to New Zealand with a fouled hull or treated by in-water cleaning. Those vessels intending longer periods of visit to New Zealand and/or that have large amounts of biofouling should potentially be refused entry.

4.13.3 Resources

Government would need to allocate resources to publicise the proposed biofouling management measures at the IMO, in accordance with New Zealand's obligations under UNCLOS for environmental protection measures that may affect entry of foreign vessels into its ports (See Section 2). The measure would also require a period of grace to allow vessel companies to modify their operations sufficiently to meet the proposed IHS.

The direct and indirect costs associated with refusal of entry at the border are likely to be substantial for passenger, merchant and fishing vessels (see Section 3). Because of these costs, cruise line companies, shipping agents, cargo owners and/or passengers may seek to challenge the decision legally and/or seek compensation for financial losses. Resources would need to be reserved by Government to cover legal advice and potential compensation (See Section 4.2).

Additional resources may be required for Coastwatch operations to ensure that recreational and other small vessels that have been instructed to leave New Zealand waters do not enter coastal embayments and waters surrounding offshore islands.

4.13.4 Opportunities/Barriers

There are no additional pollution risks associated with refusal of entry at the border.

As outlined in Section 4.2, New Zealand has an obligation under UNCLOS to fore-warn shipping states (and charterers of those vessels) of any marine protection requirements that may affect entry of foreign vessels into its ports. Powers to refuse entry of a vessel to New Zealand are contained under Section 397 of the *Maritime Transport Act* (see Section 4.2). Where the decision is found to have been in breach of any marine protection convention, Maritime New Zealand may be liable to pay compensation to the owner and charterer for any losses incurred as a result of the decision (MTA section 398 (4)).

Recreational vessels

As discussed in Section 4.2, it is unclear how refusal of entry may be enforced for recreational vessels as it will not be possible to determine accurately if the vessel is not compliant with the Import Health Standard for Biofouling using pre-arrival information. Refusal of entry on arrival may be in conflict with New Zealand's obligations under the International Convention for the Safety of Life at Sea (SOLAS), 1974 since it may oblige crews to depart without sufficient provisions or rest.

All New Zealand vessels (including yachts) going overseas must be registered as a New Zealand ship with the Registrar of Ships and have a Safety Inspection Certificate issued by Maritime New Zealand prior to departure (MNZ 12409). Not all Flag States have similar safety requirements for cruising yachts and there is considerable variability in the standards of yacht design and in the expertise of the crews that may put them at risk in bad weather. Because of their smaller size, cruising yachts are also more susceptible to hazards from bad weather conditions than are larger merchant vessels. Because of the hazards to sailing in the Pacific Islands during the cyclone season (November to the end of March), some Pacific Island nations (e.g. Cook Islands) actively discourage cruising yachts from remaining in the islands during that time of year. Yachts refused entry to New Zealand will, therefore, have to proceed to alternative destinations to avoid the cyclone season.

4.13.5 Strategic Fit

Although technically feasible, this option does not align well with the principal biosecurity outcome that New Zealand is trying to achieve:

- harmful organisms are prevented from crossing New Zealand's borders and establishing, with the assurance that trade and tourism are maintained (MAF Biosecurity New Zealand 2007)

Recreational vessels

Potential harm could be done to New Zealand's reputation as a destination for cruising yachts, if significant numbers of yachts were refused entry on arrival. New Zealand is a popular destination for international cruising yachts both for its natural sailing attractions and for the variety and reputation of refit and repair operations. These services are actively marketed overseas to the cruising yacht fraternity by the New Zealand Marine Export Group Inc. In 2008, the New Zealand marine industry exported goods and services in excess of $717 million. Over 80% of the value of these exports was comprised of superyachts, equipment and services, and yacht refits (Business New Zealand 2010).

We are not aware of any economic impact studies done in New Zealand of cruise yacht tourism. Orams (2002) estimated that cruising yachts in Tonga have an average spend of ~ NZ$30 per day (excluding major purchases such as vessel maintenance and refit). Using these figures, we might expect a typical yacht to spend a minimum of $7,740 over the course an average stay in New Zealand of 258 days (NIWA unpubl. data). Around 500 foreign-owned yachts enter New Zealand each year, meaning total earnings to local businesses of ~ $3.9 million. This does not include an estimated $1.5 million per annum of expenditure on vessel maintenance and repainting (see Section 4.2).

Fishing vessels

Refusal of entry to a FCV will cause disruption to New Zealand's deepwater fishing industry. At present, few of the vessels entering New Zealand would meet the proposed IHS for vessel biofouling and refusal of entry is likely to result in delays to fishing and an inability to fill existing quota. FCVs are currently an integral part of New Zealand's deepwater fisheries and land almost half of the total commercial catch of New Zealand fisheries (Seafood Industry Council 2010). New Zealand fishing companies depend heavily on these vessels to catch their deepwater quota. If a FCV is refused entry to New Zealand the charterer will incur costs through lost fishing revenue and time-charter costs. Flow-on indirect costs may include loss of market share or confidence if the company is not able to supply forward orders for fish products. If the vessel is not able to return or cannot be replaced in time to take part in the seasonal fishery, the company may not be able to fulfil any of its annual quota.

Passenger vessels

Refusal of entry to a passenger vessel would do significant harm to New Zealand's reputation as a tourist destination for cruise lines and their passengers. The cruise tourism industry contributes more than $182 million to the New Zealand economy each year and is continuing to grow rapidly (Market Economics Ltd 2008). It currently sustains, either directly or indirectly, 2,790 full time equivalent workers (FTEs) and each passenger that travels on a cruise ship to New Zealand generates around $1,568 in value added for the economy (Market Economics Ltd 2008). Ease of border-crossings (including customs formalities, quarantine agreements, etc.) is one of the considerations made by cruise lines in the selection of destinations (King 1999; Papatheodorou 2006). Refusal of entry on arrival would require rescheduling the vessel's itinerary and rebooking or refunding the travel plans of all passengers and crew. The potential flow-on costs to a cruise line from such a disruption at the border will be substantial and would cause cruise lines to reconsider New Zealand as a destination for visits. The magnitude of harm done to New Zealand's standing in the cruise industry would be a function of the number of non-compliant vessels that are refused entry and the manner in which this is done (e.g. if the measure was implemented without sufficient forewarning to the industry and vessel agents).

Merchant vessels

Because New Zealand is such a small trading nation, there is a significant risk to New Zealand's sea-freight trade if it introduces measures that may result in refusal of entry to a merchant vessel. New Zealand relies heavily on sea-freight for the movement of goods to and from its major international markets. The performance of New Zealand's economy relies heavily on its export sector and, because such a large proportion of its exports are carried as sea-freight, the performance of this sector is dependent on international shipping services (New Zealand Shippers' Council 2010). New Zealand's small size and remoteness from major trading partners mean that the availability and quality of its shipping services are limited and it is relatively poorly integrated into global liner shipping networks, being serviced as it is by relatively few shipping lines (Lawrence et al. 2010). Any factors that affect the efficiency, reliability and cost-effectiveness of its shipping or which put existing sea-freight services at risk may have significant flow-on effects to market delivery and export revenues (New Zealand Shippers' Council 2010). The potential for refusal of entry on arrival to New Zealand may affect these standings and be a disincentive for liner and shipping companies to include New Zealand on their itineraries if there is uncertainty around whether or not they will be granted entry. The direct and indirect costs associated with delays or disruptions to the schedules of merchant vessels are described in Section 3. Costs borne by the shipping line through refusal of entry, including the need to re-schedule services or shipping cargo, will ultimately be passed on to the costs of imported and exported goods, increasing prices to New Zealand consumers and reducing the competitiveness of New Zealand export goods in overseas markets. Because of the large costs to shipping lines and cargo owners and potential damage to the New Zealand exports, refusal of entry into New Zealand is likely to result in litigation from shipping companies and/or cargo owners to challenge the decision and seek compensation for financial losses.

The magnitude of harm done to New Zealand's sea freight markets would be a function of the number of non-compliant vessels that are refused entry and the manner in which this is done (e.g. if the measure was implemented without sufficient forewarning to the industry and vessel agents).

4.13.6 Net Benefit

Although refusal of entry is a technically feasible option that would result in a substantial reduction in biosecurity risk for vessels visiting New Zealand for longer than 1 day, it is has the potential to harm New Zealand's sea-freight and exports, its deepwater fishing industry and its reputation as a destination for cruising yachts and passenger vessels. The extent of harm will depend on the frequency with which vessels are refused entry. Currently, large proportions of these vessels entering New Zealand are not compliant with the proposed IHS. Use of refusal of entry as a biofouling management tool would need to be preceded by adequate notice to international shipping and a period of grace to allow vessel operators to align their husbandry practices with the proposed IHS and other measures being promoted internationally by the IMO.

Nevertheless, there are currently few options available for managing biofouling on large (> 50 m) vessels in New Zealand. *Refusal of entry* should be considered as an option when the biosecurity risk from a vessel is assessed as being high. This is likely to be when the vessel has significant amounts of biofouling and is likely to remain in New Zealand waters for more than a few days. Although the establishment of non-indigenous organisms is a highly stochastic process, the risk is likely to increase the longer the vessel remains untreated in New Zealand waters. *Refusal of entry* is one of few options available to mitigate this risk for large vessels.

5 Summary of Recommended Management Options for each Scenario

Draft decision trees for each of the scenarios of non-compliance are provided in Appendix 2. In this section, we provide brief narrative summaries of the recommended management options for each scenario to aid use of the decision trees.

5.1 RECREATIONAL VESSELS

5.1.1 Rapid turn-around (< 24 h): Single port visit

Because of the time they take to reach New Zealand few, if any, recreational vessels are likely to fall into this scenario (Table 4). The biofouling management options that are not feasible for recreational vessels with rapid (< 24 h) turn-around times are:

- in-water cleaning by mechanical methods;
- in-water cleaning by encapsulation;
- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by desiccation.

Of those options that are currently feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition. Refusal of entry is likely to impose the greatest inconvenience on vessel owners and may represent a safety hazard if the vessel is already in New Zealand waters and needs to re-provision. Given the relatively short turn-around times of the vessels (< 24 h) the net benefits of treatment may be marginal since the relative risk of establishment of non-indigenous species is likely to be low compared to longer periods of stay. The education of vessel masters option involves the least cost and inconvenience to vessel owners, but still entails some (possibly minor) biosecurity risk while the vessel is still in New Zealand. It is the recommended option for vessels with very low densities or small patches of biofouling (such as may occur in niche areas).

Haul-out and cleaning by water blasting provides the greatest net benefit for mitigation of biosecurity risk. It is the preferred option for very heavily fouled vessels. However, the ability to implement treatments involving haul-out of the vessel within 24 h will depend on demand for local services at the time the vessel arrives in port. During peak periods of arrival of recreational vessels, demand for haul-out services may outstrip current resources and priority should be given to vessels that are planning to stay longer in New Zealand, since these vessels are likely to present greater biosecurity risk. In these circumstances, non-compliant vessels with rapid turn-around should be issued with educational materials and a warning to be free from biofouling if returning to New Zealand.

5.1.2 Rapid turn-around (< 24 h): Multiple ports

The biofouling management options that are not feasible for rapid (< 24 h) turn-around times are:

- in-water cleaning by mechanical methods;
- in-water cleaning by encapsulation;
- in-water cleaning by heat treatment;

- in-water cleaning by freshwater treatment;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing (“baseline”) condition. The education of vessel masters option involves the least cost and inconvenience to vessel owners, but entails significant biosecurity risk if the vessel is allowed to continue onto other destinations in New Zealand. Refusal of entry is likely to impose the greatest inconvenience on vessel owners, may represent a safety hazard if the vessel is already in New Zealand waters and could damage New Zealand’s reputation as a destination for cruising yachts.

Haul-out and cleaning by water blasting provides the greatest net benefit for mitigation of biosecurity risk. It is the recommended option for all non-compliant vessels that are visiting multiple ports in New Zealand. The ability to implement haul-out treatments will depend on demand for local facilities at the time the vessel arrives in port. If facilities are not available in the port of first entry, the vessel should be instructed to sail directly to the nearest port-of-call with available haul-out facilities. For very heavily fouled vessels or in circumstances where there are no facilities available, refusal of entry to subsequent ports of call should be considered as an option.

5.1.3 Short-term turn-around (1-14 days): Single port

The management options that are not feasible for short-term turn-around of vessels are:

- in-water cleaning by mechanical methods;
- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing (“baseline”) condition. The education of vessel masters option involves the least cost and inconvenience to vessel owners, but entails significant biosecurity risk if the vessel is allowed to remain untreated in New Zealand waters for extended periods (up to 14 days). Refusal of entry is likely to impose the greatest inconvenience on vessel owners, may represent a safety hazard if the vessel is already in New Zealand waters and could damage New Zealand’s reputation as a destination for cruising yachts. Encapsulation will reduce biosecurity risk relative to the no action option, but there is uncertainty over its efficacy and the time required to achieve 100% biofouling mortality. For short-term stays it may be the preferred option when there are no haul-out facilities available. Haul-out and water blasting is the recommended option for all non-compliant vessels. Haul-out services are widely available in New Zealand and represent relatively low biosecurity risk if the vessel is removed from the water soon after arrival. In-water cleaning by accredited facilities is recommended for vessels with low levels of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Because the costs of in-water cleaning and haul-out are similar for recreational vessels, haul-out should be the preferred option where appropriate facilities are available.

5.1.4 Short-term turn-around (1-14 days): Multiple ports

The management options that are not feasible for short-term turn-around of vessels are:

- in-water cleaning by mechanical methods;
- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition. The education of vessel masters option involves the least cost and inconvenience to vessel owners, but entails significant biosecurity risk if the vessel is allowed to remain untreated in New Zealand waters for extended periods (up to 14 days). Refusal of entry is likely to impose the greatest inconvenience on vessel owners, may represent a safety hazard if the vessel is already in New Zealand waters and could damage New Zealand's reputation as a destination for cruising yachts. Encapsulation will reduce biosecurity risk relative to the no action option, but there is uncertainty over its efficacy and the time required to achieve 100% biofouling mortality. For short-term stays it may be the preferred option for heavily fouled vessels when there are no haul-out facilities available. Haul-out and water blasting is the recommended option for all non-compliant vessels. Haul-out services are widely available in New Zealand and represent relatively low biosecurity risk if the vessel is removed from the water soon after arrival. In-water cleaning by accredited facilities is only recommended for vessels with low levels of biofouling ("spot fouling") where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Because the costs of in-water cleaning and haul-out are similar for recreational vessels, haul-out should be the preferred option where appropriate facilities are available.

5.1.5 Long-term turn-around (> 14 days): Single port

Management options that are not feasible for long-term turn-around of recreational vessels are:

- in-water cleaning by mechanical methods;
- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition. The education of vessel masters option involves the least cost and inconvenience to vessel owners, but entails significant biosecurity risk if the vessel is allowed to remain untreated in New Zealand waters for extended periods (> 14 days). Refusal of entry is likely to impose the greatest inconvenience on vessel owners, may represent a safety hazard if the vessel is already in New Zealand waters and could damage New Zealand's reputation as a destination for cruising yachts. Encapsulation will reduce biosecurity risk relative to the no action option, but there is uncertainty over its efficacy and the time required to achieve 100% mortality of biofouling. For long-term stays it may be the preferred option for heavily fouled vessels when there are no haul-out facilities available. Haul-out and water blasting is the recommended option for all non-compliant vessels. Haul-out services are widely available in New Zealand and represent relatively low biosecurity risk if the vessel is removed from the water soon after arrival. In-water cleaning by accredited facilities is only recommended for vessels with low levels of biofouling ("spot fouling") where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Because the costs of in-water cleaning and haul-out are similar for recreational vessels, haul-out should be the preferred option where appropriate facilities are available.

5.1.6 Long-term turn-around (> 14 days): Multiple ports

Management options that are not feasible for long-term turn-around of recreational vessels are:

- in-water cleaning by mechanical methods;
- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition. The education of vessel masters option involves the least cost and inconvenience to vessel owners, but entails significant biosecurity risk if the vessel is allowed to remain untreated in New Zealand waters for extended periods (> 14 days). Refusal of entry is likely to impose the greatest inconvenience on vessel owners, may represent a safety hazard if the vessel is already in New Zealand waters and could damage New Zealand's reputation as a destination for cruising yachts. Encapsulation will reduce biosecurity risk relative to the no action option, but there is uncertainty over its efficacy and the time required to achieve 100% biofouling mortality. For long-term stays it may be the preferred option for heavily fouled vessels when there are no haul-out facilities available. Haul-out and water blasting is the recommended option for all non-compliant vessels. Haul-out services are widely available in New Zealand and represent relatively low biosecurity risk if the vessel is removed from the water soon after arrival. In-water cleaning by accredited facilities is only recommended for vessels with low densities or small patches of biofouling ("spot fouling") where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Because the costs of in-water cleaning and haul-out are similar for recreational vessels, haul-out should be the preferred option where appropriate facilities are available.

5.2 FISHING VESSELS

5.2.1 Rapid turn-around (< 24 hrs): Single port visit

The biofouling management options that are not feasible for fishing vessels with rapid turn-around times are:

- in-water cleaning by hand;
- in-water cleaning by encapsulation;
- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by scraping;
- haul-out and cleaning by waterblasting;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel within 24 h using in-water removal by mechanical methods. Mechanical removal is currently the most feasible of the in-water cleaning options for large vessels with rapid turn-around times. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work. In-water cleaning by accredited facilities is possible for vessels with low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities.

Where there are no decontamination facilities available, the recommended option for non-compliant vessels with low levels of biofouling ("spot biofouling") is to issue them with educational materials and a warning for repeat visits. Given the relatively short turn-around times of the vessels (< 24 h) the net benefits of treatment may be marginal since the relative risk of establishment of non-indigenous species is likely to be low compared to longer periods of stay. Education of vessel masters involves the least cost and inconvenience to vessel owners, but still entails some biosecurity risk. For heavily fouled vessels, education of vessel masters is the preferred option in the short-term, but in severe cases consideration should be given to refusal of entry or in-water cleaning to mitigate risk. Refusal of entry is likely to impose the greatest inconvenience and cost on vessel owners and charterers. It should be applied only to heavily fouled vessels that have received prior warning of non-compliance.

5.2.2 Rapid turn-around (< 24 h): Multiple ports

The biofouling management options that are not feasible for fishing vessels with short-term turn-around times are:

- in-water cleaning by encapsulation;
- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by scraping;
- haul-out and cleaning by waterblasting;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel using in-water removal by hand or mechanical methods. In-water cleaning by accredited facilities is possible for vessels with low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Mechanical removal is currently the most feasible of the in-water cleaning options for large vessels with low densities or small patches of biofouling to mitigate the immediate biosecurity risk. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work. In-water cleaning by accredited facilities is possible for non-compliant vessels where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities.

Where in-water decontamination facilities are not available at the port of first entry, the vessel should be instructed to undergo cleaning at an approved facility at the next port of call. Where no decontamination facilities are available, consideration should be given to refusal of entry, particularly for heavily fouled vessels. Refusal of entry is likely to impose the greatest inconvenience and cost on vessel owners and charterers. It should only be implemented for vessels that have heavy biofouling and which have received warnings for non-compliance.

5.2.3 Short-term turn-around (1-14 days): Single port

The biofouling management options that are not feasible for fishing vessels with short-term turn-around times are:

- in-water cleaning by encapsulation;
- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by scraping;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel using in-water removal by hand or mechanical methods. In-water cleaning by accredited facilities is possible for vessels with low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities. Mechanical removal is currently the most feasible of the in-water cleaning options for large vessels with low densities or small patches of biofouling to mitigate the immediate biosecurity risk. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work.

For heavily fouled fishing vessels that have entered ports of arrival with suitable dry-dock or slip-way facilities (e.g. Lyttelton, Auckland, Nelson, Whangarei) it may be possible to have the vessel removed from the water and cleaned by water-blasting. This is the recommended option for heavily fouled vessels when these facilities are available. Haul-out and cleaning by water-blasting is consistent with the fishing industry's own Code of Practice for biofouling on FCVs. Options involving haul-out will depend on the size of the vessel and the demand for local facilities. Dry-docks and slipways are often in high demand and cannot accommodate very large fishing vessels (see Table 22 and Table 23). The longer the vessel remains untreated, the greater is the likelihood that organisms may establish from it.

Where appropriate decontamination facilities are not available, education of vessel masters and refusal of entry are the most viable options for short-term visits. Refusal of entry is likely to impose the greatest inconvenience and cost on vessel owners and charterers. It should only be implemented for vessels that have heavy biofouling and which have received warnings for non-compliance.

5.2.4 Short-term turn-around (1-14 days): Multiple ports

The biofouling management options that are not feasible for fishing vessels with short-term turn-around times are:

- in-water cleaning by encapsulation;
- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by scraping;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel using in-water removal by hand or mechanical methods. In-water cleaning by accredited facilities is possible for vessels with low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Mechanical removal is currently the most feasible of the in-water cleaning options for large vessels with low densities or small patches of biofouling to mitigate the immediate biosecurity risk. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work. In-water cleaning by accredited facilities is possible for non-compliant vessels where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities.

For heavily fouled fishing vessels that have entered ports of arrival with suitable dry-dock or slip-way facilities (e.g. Lyttelton, Auckland, Nelson, Whangarei) it may be possible to have the vessel removed from the water and cleaned by water-blasting. This is the recommended option for heavily fouled vessels when these facilities are available. Haul-out and cleaning by water-blasting is consistent with the fishing industry's own Code of Practice for biofouling on FCVs. Options involving haul-out will depend on the size of the vessel and the demand for local facilities. Dry-docks and slipways are often in high demand and cannot accommodate very large fishing vessels (see Table 22 and Table 23). The longer the vessel remains untreated, the greater is the likelihood that organisms may establish from it.

Where decontamination facilities are not available at the port of first entry, the vessel should be instructed to proceed directly to an approved (and available) cleaning facility at another New Zealand port. Where no decontamination facilities are available, consideration should be given to refusal of entry, particularly for heavily fouled vessels. Refusal of entry is likely to impose the greatest inconvenience and cost on vessel owners and charterers. It should only be implemented for vessels that have heavy biofouling and which have received warnings for non-compliance.

5.2.5 Long-term turn-around (> 14 days): Single port

The biofouling management options that are not feasible for fishing vessels with long-term turn-around times are:

- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by scraping;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Encapsulation has been shown to mitigate biosecurity risk relative to the no action option. However, this technology is still considered in development and there are some uncertainties regarding the minimum time required for encapsulation to be effective (with or without addition of biocides) and its effect on antifouling coatings. Commercial encapsulation services are not currently available in New Zealand ports of entry, but there is commercial experience with its application to small and large vessels. It may be a viable option to mitigate biosecurity risk for heavily fouled vessels with long-term stays where there is no available decontamination facility (i.e. accredited in-water cleaning facilities). Multiple encapsulation facilities would be required in busy ports of first entry during peak periods of arrival.

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel using in-water removal by hand or mechanical methods. In-water cleaning by accredited facilities is possible for vessels with low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Mechanical removal is currently the most feasible of the in-water cleaning options for large vessels with low densities or small patches of biofouling to mitigate the immediate biosecurity risk. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work. In-water cleaning by accredited facilities is possible for non-compliant vessels where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities.

For heavily fouled fishing vessels that have entered ports of arrival with suitable dry-dock or slip-way facilities (e.g. Lyttelton, Auckland, Nelson, Whangarei) it may be possible to have the vessel removed from the water and cleaned by water-blasting. This is the recommended option for heavily fouled vessels when these facilities are available. Haul-out and cleaning by water-blasting is consistent with the fishing industry's own Code of Practice for biofouling on FCVs. Options involving haul-out will depend on the size of the vessel and the demand for local facilities. Dry-docks and slipways are often in high demand and cannot accommodate very large vessels (see Table 22 and Table 23). The longer the vessel remains untreated, the greater is the likelihood that organisms may establish from it.

Where appropriate decontamination facilities are not available, consideration should be given to refusal of entry, particularly for heavily fouled vessels. Refusal of entry is likely to impose the greatest inconvenience and cost on vessel owners and charterers. It should only be implemented for vessels that have heavy biofouling and which constitute a large biosecurity risk to New Zealand.

5.2.6 Long-term turn-around (> 14 days): Multiple ports

The biofouling management options that are not feasible for fishing vessels with long-term turn-around times are:

- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by scraping;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Encapsulation has been shown to mitigate biosecurity risk relative to the no action option. However, this technology is still considered in development and there are some uncertainties regarding the minimum time required for encapsulation to be effective (with or without addition of biocides) and its effect on antifouling coatings. Commercial encapsulation services are not currently available in New Zealand ports of entry, but there is commercial experience with its application to small and large vessels. It may be a viable option to mitigate biosecurity risk for heavily fouled vessels with long-term stays when there is no decontamination facility available (i.e. accredited in-water cleaning facilities). Multiple encapsulation facilities would be required in busy ports of first entry during peak periods of arrival

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel using in-water removal by hand or mechanical methods. In-water cleaning by accredited facilities is possible for vessels with low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Mechanical removal is currently the most feasible of the in-water cleaning options for large vessels with low densities or small patches of biofouling to mitigate the immediate biosecurity risk. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work. In-water cleaning by accredited facilities is possible for non-compliant vessels where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities.

For heavily fouled fishing vessels that have entered ports of arrival with suitable dry-dock or slip-way facilities (e.g. Lyttelton, Auckland, Nelson, Whangarei) it may be possible to have the vessel removed from the water and cleaned by water-blasting. This is the recommended option for heavily fouled vessels when these facilities are available. Haul-out and cleaning by water-blasting is consistent with the fishing industry's own Code of Practice for biofouling on FCVs. Options involving haul-out will depend on the size of the vessel and the demand for local facilities. Dry-docks and slipways are often in high demand and cannot accommodate very large vessels (see Table 22 and Table 23). The longer the vessel remains untreated, the greater is the likelihood that organisms may establish from it.

Where decontamination facilities are not available at the port of first entry, the vessel should be instructed to proceed directly to an approved (and available) cleaning facility at another New Zealand port. Where no decontamination facilities are available, consideration should be given to refusal of entry, particularly for heavily fouled vessels. Refusal of entry is likely to impose the greatest inconvenience and cost on vessel owners and charterers. It should only be implemented for vessels that have heavy biofouling and which have received warnings for non-compliance.

5.3 PASSENGER VESSELS

5.3.1 Rapid turn-around (< 24 hrs): Single port visit

The biofouling management options that are not feasible for passenger vessels with rapid turn-around times are:

- in-water cleaning by hand;
- in-water cleaning by encapsulation;
- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by scraping;
- haul-out and cleaning by waterblasting;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel within 24 h using in-water removal by mechanical methods. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work. In-water cleaning by accredited facilities may be possible for vessels that have low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities.

Where there are no decontamination facilities available, the recommended option for non-compliant vessels with low densities or small patches of biofouling ("spot biofouling") is to issue them with educational materials and a warning for repeat visits. Given the relatively short turn-around times of the vessels (< 24 h) the net benefits of treatment may be marginal since the relative risk of establishment of non-indigenous species is likely to be low compared to longer periods of stay. Education of vessel masters involves the least cost and inconvenience to vessel owners, but still entails some (possibly minor) biosecurity risk for vessels with rapid turn-around times and low densities or small patches of biofouling. For heavily fouled vessels, education of vessel masters is the preferred option in the short-term with a warning about the potential for refusal of entry if the vessel returns to New Zealand with biofouling. Refusal of entry is likely to impose the greatest inconvenience on vessel owners and passengers and may harm New Zealand's reputation as a stop-over for round-the-world cruises (which tend to be the cruises that are present in a single New Zealand port for < 24 h). It should be applied only to heavily fouled vessels that have received prior warning of non-compliance.

5.3.2 Rapid turn-around (< 24 h): Multiple ports

The biofouling management options that are not feasible for passenger vessels with rapid turn-around times are:

- in-water cleaning by hand;
- in-water cleaning by encapsulation;
- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by scraping;
- haul-out and cleaning by waterblasting;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel within 24 h using in-water removal by mechanical methods. Mechanical removal is currently the most feasible of the in-water cleaning options for large vessels with low densities or small patches of biofouling. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work. In-water cleaning by accredited facilities is possible for vessels with low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities.

Where there are no decontamination facilities available, the recommended option for non-compliant vessels with low densities or small patches of biofouling ("spot biofouling") is to issue them with educational materials and a warning for repeat visits. Education of vessel masters involves the least cost and inconvenience to vessel owners, but still entails some biosecurity risk. For heavily fouled vessels, education of vessel masters is the preferred option in the short-term, but in severe cases consideration should be given to refusal of entry or in-water cleaning to mitigate risk. Refusal of entry is likely to impose the greatest inconvenience and cost on vessel owners and passengers and may harm New Zealand's reputation as a stop-over for round-the-world cruises (which tend to be the cruises that are present in a single New Zealand port for < 24 h). It should be applied only to heavily fouled vessels that have received prior warning of non-compliance.

5.3.3 Short-term turn-around (1-14 days): Single port

The biofouling management options that are not feasible for passenger vessels with short-term turn-around times are:

- in-water cleaning by encapsulation;
- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;

- haul-out and cleaning by scraping;
- haul-out and cleaning by waterblasting;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel using in-water removal by hand or mechanical methods. In-water cleaning by accredited facilities is possible for vessels with low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities. Mechanical removal is currently the most feasible of the in-water cleaning options for large vessels with low densities or small patches of biofouling to mitigate the immediate biosecurity risk. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work.

Where appropriate decontamination facilities are not available, education of vessel masters and refusal of entry are the most viable options for short-term visits. Refusal of entry is likely to impose the greatest inconvenience on vessel owners and passengers and will do significant harm to New Zealand's reputation as a destination for cruise tourism. It should only be implemented for vessels that have heavy biofouling and which have received warnings for non-compliance.

5.3.4 Short term turn-around (1-14 days): Multiple ports

The biofouling management options that are not feasible for passenger vessels with short-term turn-around times are:

- in-water cleaning by encapsulation;
- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by scraping;
- haul-out and cleaning by waterblasting;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel using in-water removal by hand or mechanical methods. In-water cleaning by accredited facilities is possible for vessels with low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Mechanical removal is currently the most feasible of the in-water cleaning options for large vessels with low densities or small patches of biofouling to mitigate the immediate biosecurity risk. Although there are currently few companies with mechanical cleaning equipment in

New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work. In-water cleaning by accredited facilities is possible for non-compliant vessels where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities.

Where in-water decontamination facilities are not available at the port of first entry, the vessel should be instructed to proceed directly to the next port of call to undergo cleaning at an approved facility. Where no decontamination facilities are available, consideration should be given to refusal of entry, particularly for heavily fouled vessels. Refusal of entry is likely to impose the greatest inconvenience and cost on vessel owners and passengers and will do significant harm to New Zealand's reputation as a destination for cruise tourism. It should only be implemented for vessels that have heavy biofouling and which have received warnings for non-compliance.

5.3.5 Long term turn-around (> 14 days): Single port

The biofouling management options that are not feasible for passenger vessels with long-term turn-around times are:

- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by scraping;
- haul-out and cleaning by waterblasting;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Encapsulation has been shown to mitigate biosecurity risk relative to the no action option. However, this technology is still considered in development and there are some uncertainties regarding the minimum time required for encapsulation to be effective (with or without addition of biocides) and its effect on antifouling coatings. Commercial encapsulation services are not currently available in New Zealand ports of entry, but there is commercial experience with its application to small and large vessels. It may be a viable option to mitigate biosecurity risk for heavily fouled vessels with long-term stays where there is no available decontamination facility (i.e. accredited in-water cleaning facilities). Multiple encapsulation facilities would be required in busy ports of first entry during peak periods of arrival.

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel using in-water removal by hand or mechanical methods. In-water cleaning by accredited facilities is possible for vessels with low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Mechanical removal is currently the most feasible of the in-water cleaning options for large vessels with low densities or small patches of biofouling to mitigate the immediate biosecurity risk. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work. In-water cleaning by accredited facilities is possible for non-compliant vessels where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities.

Where appropriate decontamination facilities are not available, consideration should be given to refusal of entry, particularly for heavily fouled vessels. Refusal of entry is likely to impose the greatest inconvenience and cost on vessel owners and passengers and will do significant harm to New Zealand's reputation as a destination for cruise tourism. It should only be implemented for vessels that have heavy biofouling and which constitute a large biosecurity risk to New Zealand.

5.3.6 Long term turn-around (> 14 days): Multiple ports

The biofouling management options that are not feasible for passenger vessels with long-term turn-around times are:

- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by scraping;
- haul-out and cleaning by waterblasting;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Encapsulation has been shown to mitigate biosecurity risk relative to the no action option. However, this technology is still considered in development and there are some uncertainties regarding the minimum time required for encapsulation to be effective (with or without addition of biocides) and its effect on antifouling coatings. Commercial encapsulation services are not currently available in New Zealand ports of entry, but there is commercial experience with its application to small and large vessels. It may be a viable option to mitigate biosecurity risk for heavily fouled vessels with long-term stays when there is no decontamination facility available (i.e. accredited in-water cleaning facilities). Multiple encapsulation facilities would be required in busy ports of first entry during peak periods of arrival.

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel using in-water removal by hand or mechanical methods. In-water cleaning by accredited facilities is possible for vessels with low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Mechanical removal is currently the most feasible of the in-water cleaning options for large vessels with low densities or small patches of biofouling to mitigate the immediate biosecurity risk. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work. In-water cleaning by accredited facilities is possible for non-compliant vessels where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities.

Where in-water decontamination facilities are not available at the port of first entry, the vessel should be instructed to proceed directly to the next port of call to undergo cleaning at an approved facility. Where no decontamination facilities are available, consideration should be given to refusal of entry, particularly for heavily fouled vessels. Refusal of entry is likely to impose the greatest inconvenience and cost on vessel owners and passengers and will do significant harm to New Zealand's reputation as a destination for cruise tourism. It should only be implemented for vessels that have heavy biofouling and which have received warnings for non-compliance.

5.4 MERCHANT VESSELS

5.4.1 Rapid turn-around (< 24 hrs): Single port visit

The biofouling management options that are not feasible for merchant vessels with rapid turn-around times are:

- in-water cleaning by hand;
- in-water cleaning by encapsulation;
- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by scraping;
- haul-out and cleaning by waterblasting;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel within 24 h using in-water removal by mechanical methods. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work. In-water cleaning by accredited facilities may be possible for vessels that have low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities.

Where there are no decontamination facilities available, the recommended option for non-compliant vessels with low densities or small patches of biofouling ("spot biofouling") is to issue them with educational materials and a warning for repeat visits. Given the relatively short turn-around times of the vessels (< 24 h) the net benefits of treatment may be marginal since the relative risk of establishment of non-indigenous species is likely to be low compared to longer periods of stay. Education of vessel masters involves the least cost and inconvenience to vessel owners, but still entails some (possibly minor) biosecurity risk for vessels with rapid turn-around times and low densities or small patches of biofouling. For heavily fouled vessels, education of vessel masters is the preferred option in the short-term with a warning about the potential for refusal of entry if the vessel returns to New Zealand with biofouling. Refusal of entry is likely to impose the greatest inconvenience and cost on the vessel operator and cargo owners and will result in significant direct and indirect costs to the shipping line and possible damage to New Zealand's sea-freight cargo services if the measures are introduced unilaterally. After an initial period of implementation and international notification, refusal of entry should be phased in as the preferred option for vessels that continue to enter New Zealand with heavy biofouling.

5.4.2 Rapid turn-around (< 24 h): Multiple ports

The biofouling management options that are not feasible for merchant vessels with rapid turn-around times are:

- in-water cleaning by hand;
- in-water cleaning by encapsulation;
- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by scraping;
- haul-out and cleaning by waterblasting;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel within 24 hrs using in-water removal by mechanical methods. Mechanical removal is currently the most feasible of the in-water cleaning options for large vessels with low densities or small patches of biofouling. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work. In-water cleaning by accredited facilities is possible for vessels with low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities.

Where there are no decontamination facilities available, the recommended option for non-compliant vessels with low densities or small patches of biofouling ("spot biofouling") is to issue them with educational materials and a warning for repeat visits. Education of vessel masters involves the least cost and inconvenience to vessel owners, but still entails some biosecurity risk. For heavily fouled vessels, education of vessel masters is the preferred option in the short-term, but in severe cases consideration should be given to refusal of entry or in-water cleaning to mitigate risk. Refusal of entry is likely to impose the greatest inconvenience and cost on the vessel operator and cargo owners and will result in significant direct and indirect costs to the shipping line and possible damage to New Zealand's sea-freight cargo services if the measures are introduced unilaterally. After an initial period of implementation and international notification, refusal of entry should be phased in as the preferred option for vessels that continue to enter New Zealand with heavy biofouling.

5.4.3 Short-term turn-around (1-14 days): Single port

The biofouling management options that are not feasible for merchant vessels with short-term turn-around times are:

- in-water cleaning by encapsulation;
- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by scraping;
- haul-out and cleaning by waterblasting;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel using in-water removal by hand or mechanical methods. In-water cleaning by accredited facilities is possible for vessels with low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities. Mechanical removal is currently the most feasible of the in-water cleaning options for large vessels with low densities or small patches of biofouling to mitigate the immediate biosecurity risk. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work. Large (> 200 m), very heavily fouled vessels may take up to 5 days to be cleaned using mechanical methods (Table 17). Most merchant vessels are in port for periods of < 3 days (Table 4) meaning that these vessels may be delayed if they are to be treated effectively. Similarly, for safety reasons, vessels carrying volatile cargoes may not allow in-water cleaning to take place while the vessel is loading or unloading. In the short-term, it may be most practical to issue these vessels with educational materials and a warning if they are likely to be in New Zealand waters for < 3 days. After an initial period of implementation and international notification, refusal of entry should be phased in as the preferred option for vessels that continue to enter New Zealand with very heavy biofouling.

Where appropriate decontamination facilities are not available, education of vessel masters and refusal of entry are the most viable options for short-term visits. Refusal of entry is likely to impose the greatest inconvenience and cost on the vessel operator and cargo owners and will result in significant direct and indirect costs to the shipping line and possible damage to New Zealand's sea-freight cargo services if the measures are introduced unilaterally. After an initial period of implementation and international notification, refusal of entry should be phased in as the preferred option for vessels that continue to enter New Zealand with heavy biofouling.

5.4.4 Short term turn-around (1-14 days): Multiple ports

The biofouling management options that are not feasible for merchant vessels with short-term turn-around times are:

- In-water cleaning by encapsulation;
- In-water cleaning by heat treatment;
- In-water cleaning by freshwater treatment;
- Haul-out and cleaning by scraping;
- Haul-out and cleaning by waterblasting;

- Haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel using in-water removal by hand or mechanical methods. In-water cleaning by accredited facilities is possible for vessels with low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Mechanical removal is currently the most feasible of the in-water cleaning options for large vessels with low densities or small patches of biofouling to mitigate the immediate biosecurity risk. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work. Large (> 200 m), very heavily fouled vessels may take up to 5 days to be cleaned using mechanical methods (Table 17). Most merchant vessels are in port for periods of < 3 days (Table 4) meaning that these vessels may be delayed if they are to be treated effectively. Similarly, for safety reasons, vessels carrying volatile cargoes may not allow in-water cleaning to take place while the vessel is loading or unloading. In the short-term, it may be most practical to issue these vessels with educational materials and a warning if they are likely to be in New Zealand waters for < 3 days. In-water cleaning by accredited facilities is possible for non-compliant vessels where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities.

Where in-water decontamination facilities are not available at the port of first entry, the vessel should be instructed to proceed directly to the next port of call to undergo cleaning at an approved facility. Where no decontamination facilities are available, consideration should be given to refusal of entry, particularly for heavily fouled vessels. Where appropriate decontamination facilities are not available, education of vessel masters and refusal of entry are the most viable options for short-term visits. Refusal of entry is likely to impose the greatest inconvenience and cost on the vessel operator and cargo owners and will result in significant direct and indirect costs to the shipping line and possible damage to New Zealand's sea-freight cargo services if the measures are introduced unilaterally. After an initial period of implementation and international notification, refusal of entry should be phased in as the preferred option for vessels that continue to enter New Zealand with heavy biofouling.

5.4.5 Long term turn-around (> 14 days): Single port

The biofouling management options that are not feasible for merchant vessels with long-term turn-around times are:

- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by scraping;
- haul-out and cleaning by waterblasting;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Encapsulation has been shown to mitigate biosecurity risk relative to the no action option. However, this technology is still considered in development and there are some uncertainties regarding the minimum time required for encapsulation to be effective (with or without addition of biocides) and its effect on antifouling coatings. Commercial encapsulation services are not currently available in New Zealand ports of entry, but there is commercial experience with its application to small and large vessels. It may be a viable option to mitigate biosecurity risk for heavily fouled vessels with long-term stays where there is no available decontamination facility (i.e. accredited in-water cleaning facilities). Multiple encapsulation facilities would be required in busy ports of first entry during peak periods of arrival.

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel using in-water removal by hand or mechanical methods. In-water cleaning by accredited facilities is possible for vessels with low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Mechanical removal is currently the most feasible of the in-water cleaning options for large vessels with low densities or small patches of biofouling to mitigate the immediate biosecurity risk. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work. In-water cleaning by accredited facilities is possible for non-compliant vessels where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities.

Where appropriate decontamination facilities are not available, education of vessel masters and refusal of entry are the most viable options for long-term visits. Refusal of entry is likely to impose the greatest inconvenience and cost on the vessel operator and cargo owners and will result in significant direct and indirect costs to the shipping line and possible damage to New Zealand's sea-freight cargo services if the measures are introduced unilaterally. After an initial period of implementation and international notification, refusal of entry should be phased in as the preferred option for vessels that continue to enter New Zealand with heavy biofouling.

5.4.6 Long term turn-around (> 14 days): Multiple ports

The biofouling management options that are not feasible for merchant vessels with long-term turn-around times are:

- in-water cleaning by heat treatment;
- in-water cleaning by freshwater treatment;
- haul-out and cleaning by scraping;
- haul-out and cleaning by waterblasting;
- haul-out and cleaning by desiccation.

Of those options that are feasible, the no action option provides the least net benefit to New Zealand, since it does not mitigate the biosecurity risk relative to the existing ("baseline") condition.

Encapsulation has been shown to mitigate biosecurity risk relative to the no action option. However, this technology is still considered in development and there are some uncertainties regarding the minimum time required for encapsulation to be effective (with or without addition of biocides) and its effect on antifouling coatings. Commercial encapsulation services are not currently available in New Zealand ports of entry, but there is commercial experience with its application to small and large vessels. It may be a viable option to mitigate biosecurity risk for heavily fouled vessels with long-term stays when there is no decontamination facility available (i.e. accredited in-water cleaning facilities). Multiple encapsulation facilities would be required in busy ports of first entry during peak periods of arrival

Depending on the size of the vessel and amount of biofouling present on it, it may be possible to treat the vessel using in-water removal by hand or mechanical methods. In-water cleaning by accredited facilities is possible for vessels with low densities or small patches of biofouling where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Mechanical removal is currently the most feasible of the in-water cleaning options for large vessels with low densities or small patches of biofouling to mitigate the immediate biosecurity risk. Although there are currently few companies with mechanical cleaning equipment in New Zealand, the equipment is available internationally and could be acquired by New Zealand companies if there is a market for the work. In-water cleaning by accredited facilities is possible for non-compliant vessels where it can be demonstrated that the material removed can be captured effectively and discharges are not in breach of local water quality standards. Further research is needed to be able to demonstrate this to the satisfaction of consenting authorities.

Where in-water decontamination facilities are not available at the port of first entry, the vessel should be instructed proceed directly to the next port of call to undergo cleaning at an approved facility. Where appropriate decontamination facilities are not available, education of vessel masters and refusal of entry are the most viable options for long-term visits. Refusal of entry is likely to impose the greatest inconvenience and cost on the vessel operator and cargo owners and will result in significant direct and indirect costs to the shipping line and possible damage to New Zealand's sea-freight cargo services if the measures are introduced unilaterally. After an initial period of implementation and international notification, refusal of entry should be phased in as the preferred option for vessels that continue to enter New Zealand with heavy biofouling.

6 References

Abbott, A.; Abel, P.D.; Arnold, D.W.; Milne, A. (2000). Cost-benefit analysis of the use of TBT: the case for a treatment approach. *The Science of the Total Environment* 258: 5-19.

Akinfiev, T.; Janushevskis, A.; E., L. (2007). A brief survey of ship hull cleaning devices. *Transport and Engineering Mechanics* 24: 133-146.

Ansell, B.; Coates, G. (2008). Tackling marine pests. *Biosecurity Magazine* 86: 12-13.

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.

Aquenal (2009). A yacht enclosure system to mitigate biosecurity risks associated with biofouling (Developed IP Report). MAF Biosecurity New Zealand Paper No: 2009/41 prepared for MAF Biosecurity New Zealand. 14 p.

Bailey, W. (1999). Supply chain management in NZ's dairy industry. In: Coyle, W.T.; Ballenger, N. (eds). *Proceedings of the ERS Workshop: Technological Changes in the Transportation Sector—Effects on Food and Agricultural Trade.* , pp. 63-69, U.S. Department of Agriculture, Economic Research Service, Market and Trade Economics Division., Washington D.C.

Bell, A.; Phillips, S.; Georgiades, E.; Denny, C.; Kluza, D. (2011). Risk Analysis: Vessel Biofouling. A Report Prepared by the Policy and Risk Directorate, MAF Biosecurity New Zealand 155 p.

Bell, B.; Menzies, S.; Yap, M.; Kerr, G. (2008). Report to Biosecurity New Zealand on Valuing the Coastal Marine Environment: Assessing the marginal dollar value losses to an estuarine ecosystem from an aggressive alien invasive crab. Working Paper No. 6, FRST Project NIMMO501 - Valuing Biodiversity. Wellington, Nimmo-Bell. 62 p.

Bell, B.; Yap, M. (2008). Report to Biosecurity New Zealand on valuing the coastal marine environment: Assessing the marginal dollar value losses of an estuarine ecosystem from an aggressive alien invasive crab: Follow up survey of Pauatahanui Inlet. Working Paper No. 8, FRST Project NIMMO501 - Valuing Biodiversity. Wellington, Nimmo-Bell. 15 p.

Biosecurity Council (2003). Tiakina Aotearoa - Protect New Zealand. The Biosecurity Strategy for New Zealand. Prepared by the Biosecurity Council for the New Zealand Government. Wellington. 63 p.

Biosecurity New Zealand (2005). Import health standards for ships' ballast water from all countries. Issued pursuant to Section 22 of the Biosecurity Act 1993. Dated 13 June 2005. Available online <http://www.biosecurity.govt.nz/imports/non-organic/standards/ballastwater.htm>.

Bohlander, J. (2009). Review of options for in-water cleaning of ships. MAF Biosecurity New Zealand Technical Paper No: 2009/42. 34

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.

Brock, R.; Bailey-Brock, J.H.; Goody, J. (1999). A case study of the efficacy of freshwater immersion in controlling introduction of alien marine fouling communities: The USS Missouri. *Pacific Science* 53: 223-231.

Brockerhoff, E.G.; Liebhold, A.M.; Richardson, B.; Suckling, D.M. (2010). Eradication of invasive forest insects: concepts, methods, costs and benefits. *New Zealand Journal of Forestry Science* 40: S117-S135.

Business New Zealand (2010). New Zealand boat manufacturing and marine industry: June 2010. <http://business.newzealand.com/common/files/Boat-manufacturing-and-marine-industry-in-New-Zealand.pdf>. Wellington, New Zealand Department of Trade & Enterprise. 4 p.

Coutts, A. (2002). The development of incursion response tools – underwater vacuum trials: An underwater vacuum recovery and filtration system and its use in control of *Didemnum vexillum* on "Steel Mariner" barge and seabed at Picton, New Zealand Prepared for Ministry of Fisheries by:New Zealand Diving and Salvage ltd No. 35

Coutts, A.; Forrest, B. (2005). Evaluation of eradication tools for the clubbed tunicate *Styela clava*. Cawthron Client report No. 1110 54p

Coutts, A.; Forrest, B. (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: 152-164.

Coutts, A.D.M.; Sinner, J. (2004). An updated benefit-cost analysis of management options for *Didemnum vexillum* in Queen Charlotte Sound. A report prepared for Marlborough District Council. Cawthron Report No. 925. Nelson, Cawthron Institute.

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/. p.

Davidson, I.C.; McCann, L.D.; Fofonoff, P.W.; Sytsma, M.D.; Ruiz, G.M. (2008a). The potential for hull-mediated species transfers by obsolete ships on their final voyages. *Diversity and Distributions* 14: 518-529.

Davidson, I.C.; McCann, L.D.; Sytsma, M.; Ruiz, G. (2008b). Interrupting a multi-species bioinvasion vector: The efficacy of in-water cleaning for removing biofouling on obsolete vessels. *Marine Pollution Bulletin* 56: 1538–1544.

Denny, C.M. (2007). In situ Plastic Encapsulation of the NZHMS Canterbury Frigate: A Trial of a Response Tool for Marine Fouling Pests. Cawthron Report No. 1271. Prepared for MAF Biosecurity NZ. Cawthron Institute. 13 p.

Department of Conservation (2010). New Zealand Coastal Policy Statement 2010. Department of Conservation, Wellington. 28 p.

Det Norske Veritas (2007). Fishing Vessel Safety Certificate. Guidelines No. 21. Norway, Det Norske Veritas. 12 p.

Enterprise Northland (2010). Marine Engineering. Available at: http://www.northlandnz.com/work/industries/marine_engineering/; <accessed 20/08/2010>.

Ferguson, R. (2000). The effectiveness of Australia's response to the black striped mussel incursion in Darwin, Australia. A report of the marine pest incursion management workshop- 27-28 August 1999 No. 75.

Floerl, O.; Coutts, A.D.M. (2009). Potential ramifications of the global economic crisis on human-mediated dispersal of marine non-indigenous species. *Marine Pollution Bulletin* 58: 1595-1598

Floerl, O.; Inglis, G.; Dey, K.L.; Smith, A. (2009a). The importance of transport hubs in stepping-stone invasions. *Journal of Applied Ecology* 46: 37-45.

Floerl, O.; Peacock, L.; Seaward, K.; Inglis, G.J. (2009b). Phase 1: Literature review to inform the review of the ANZECC Code of Practice for Antifouling and In-water Hull Cleaning and Maintenance (1997). NIWA Client Report for the Department of Agriculture, Fisheries and Forestry (DAFF) Research Project RFQ28_2008, CHC2009-118. 125 p.

Floerl, O.; Smith, M.; Inglis, G.; Davey, N.; Seaward, K.; Johnston, O.; Fitridge, I.; Rush, N.; Middleton, C.; Coutts, A. (2008). Vessel biofouling as a vector for the introduction of non-indigenous marine species to New Zealand: Recreational yachts. MAF Biosecurity NZ Research Project ZBS2004-03A No. 175 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.

Golder Associates NZ Ltd (2008). Hull encapsulation as an incursion response tool for marine fouling organisms: a trial on a large vessel. Technical Paper No: 2007/ prepared for MAF Biosecurity New Zealand Project BO_186_2006 Wellington, 19 p.

Grant, G.E.; Hyde, N.H. (1991). Quarantine risks associated with overseas yachts arriving at New Zealand's ports. Ministry of Agriculture and Fisheries.

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. Canberra, Australian Quarantine and Inspection Service.

Hopkins, G.; Forrest, B.; Coutts, A. (2008). Determining the efficiency of incursion response tools - rotating brush technology (coupled with suction capability) Biosecurity New Zealand Technical Paper No: 2008/. A report prepared for MAF Biosecurity New Zealand Project ZBS2005-21. MAF Biosecurity New Zealand. 59 p.

Hydrex (2009). ECOTEC-STC - Evaluation of a biocide-free hull protection and antifouling system with environmental and economical benefits: Summary report. EU LIFE Project ECOTEC-STC LIFE06 ENV/B/000362. Belgium, 10 p.

Inglis, G.J.; Floerl, O. (2002). Risks to marine biosecurity associated with recreational boats. Prepared for Yachting New Zealand Ltd. NIWA Client Report CHC02/23. No. 1-47 p.

Inglis, G.J.; Floerl, O.; Ahyong, S.; Cox, S.; Unwin, M.; Ponder-Sutton, A.; Seaward, K.; Kospartov, M.; Read, G.; Gordon, D.; Hosie, A.; Nelson, W.; d'Archino, R.; Bell, A.; Kluza, D. (2010). The Biosecurity Risks Associated with Biofouling on International Vessels Arriving in New Zealand: Summary of the patterns and predictors of fouling. Biosecurity New Zealand Technical Paper No: 2008. A report prepared for MAF Biosecurity New Zealand Policy and Risk Directorate Project RFP0811321 No. 182.

Inglis, G.J.; Gust, N.; Fitridge, I.; Floerl, O.; Hayden, B.J.; Fenwick, G.D. (2006). Whangarei marina: baseline survey for non-indigenous marine species. Biosecurity New Zealand Technical Paper No: 2005/15. Prepared for Biosecurity New Zealand Post-clearance Directorate for Project ZBS2000-04. 49 pp. + Appendices.

International Association of Classification Societies (2010). Requirements Concerning Survey and Certification. IACS Requirements 2010 No. 596 p.

Buhaug, Ø.; Corbett, J.J.; Endresen, Ø.; Eyring, V.; Faber, J.; Hanayama, S.; Lee, D.S.; Lee, D.; Lindstad, H.; Markowska, A.Z.; Mjelde, A.; Nelissen, D.; Nilsen, J.; Pålsson, C.; Winebrake, J.J.; Wu, W.; Yoshida, K. (2009). Second IMO GHG Study 2009. International Maritime Organization, London. 220 p.

King, M.A. (1999). The U.S. Cruise Industry - Evaluation of National economic Development Benefits. IWR Report-99-R-8. Alexandria, Virginia, U.S. Army Corps of Engineers. 30 p.

Kite-Powell, H.L.; Hoagland, P. (2002). Economic Aspects of Right Whale Ship Strike Management Measures. Final Project Report to the National Marine Fisheries Serivce, NOAA. Order Number 40EMNF100235. Marine Policy Center, Woods Hole Oceanographic Institution. 37 p.

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.

Lawrence, R.Z.; Drzeniek Hanouz, M.; Doherty, S.; Moavenzadeh, J. (2010). The Global Enabling Trade Report 2010. Geneva, World Economic Forum. 302 p.

Leung, B.; Drake, J.M.; Lodge, D.M. (2004). Predicting invasions: Propagule pressure and the gravity of Allee effects. *Ecology* 85: 1651-1660.

Lieberman, W.H.; Dieck, T. (2002). Expanding the revenue management frontier: optimal air planning in the cruise industry. *Journal of Revenue and Pricing Management* 1: 7-24.

Lyons, B.S.B. (2007). In the drydock: an inside look at the orchestrated chaos when a ship leaves service for servicing. *Cruise Travel Magazine* September/October 2007: 38-41.

MAF Biosecurity New Zealand (2006). Risk Analysis Procedures. Version 1, 12 April 2006. Wellington, MAF Biosecurity New Zealand. 103 p.

MAF Biosecurity New Zealand (2007). Strategic Plan 2007-2012. Wellington, MAF Biosecurity New Zealand. 22 p.

MAF Biosecurity New Zealand (2010a). Draft guidance document in support of the Import Health Standard for Vessel Biofouling. Wellington, Ministry of Agriculture and Forestry. 12 p.

MAF Biosecurity New Zealand (2010b). Draft Requirements for Approval as a Decontamination Facility for Vessel Biofouling. Wellington, MAF Biosecurity New Zealand. 4 p.

MAF Biosecurity New Zealand (2010c). Import Health Standard for Vessel Biofouling (Draft). BNZ-STD-BIOFOUL. Wellington, MAF Biosecurity New Zealand. 3 p.

MAF Biosecurity New Zealand (2010d). Managing and controlling the risk posed to the marine environment from biofouling on arriving vessels. MAF Biosecurity New Zealand consultation paper 10/04. Wellington, Ministry of Agriculture and Forestry. 15 p.

MAF Biosecurity New Zealand (2010e). Policy for the Biosecurity Amendment Bill. Regulatory Impact Statement. Wellington, Ministry of Agriculture and Forestry. 68 p.

MAN Diesel (2005). Propulsion trends in container vessels. Man Diesel SE Technical Papers. Copenhagen, Denmark, 16 p.

MAN Diesel (2007a). Propulsion trends in bulk carriers. Man Diesel SE Technical Papers. 15 p.

MAN Diesel (2007b). Propulsion trends in tankers. Man Diesel SE Technical Papers. 17 p.

Maritime New Zealand (2009). Maritime Rules. Part 46 – Surveys, Certification and Maintenance. Wellington, Maritime New Zealand. 39 p.

Maritime Strategies International Ltd (2010). http://www.msiltd.com/default.asp, accessed 9/12/10.

Market Economics Ltd (2008). Economic Impacts of the 2007-2008 New Zealand Cruise Ship Season. A report prepared for Cruise New Zealand Inc. Auckland, Market Economics Ltd. 42 p.

McClary, D.J.; Nelligan, R.J. (2001). Technical guidelines for acceptable hull cleaning facilities. No. 29 p.

Minister for Biosecurity (2006). NZ joins fight against dangerous red fire ant. - Press release 15 November 2006. <http://www.beehive.govt.nz/release/nz+joins+fight+against+dangerous+red+fire+ant>

Ministry of Fisheries (2009). Quota Management System: Foreign Charter Vessels (FCV). . <http://fs.fish.govt.nz/Page.aspx?pk=81&tk=249>. Accessed 1/10/2010 p.

Ministry of Health (2004). Treatment begins in Whangaparaoa following discovery of exotic mosquito larvae. - Media release 28 January 2004 <http://www.moh.govt.nz/moh.nsf/pagesmh/2811?Open>.

New Zealand Customs Service (2009). Annual Report 2008/09. Wellington, New Zealand Customs Service. 88 p.

New Zealand Customs Service (2010). Annual Report 2009/10. Wellington, New Zealand Customs Service. 94 p.

New Zealand Fishing Industry Association. (1997). Avoiding vessel hull contamination of the New Zealand environment by fishing boats. Seafood New Zealand May: 15.

New Zealand Shippers' Council (2010). The Question of Bigger Ships: Securing New Zealand's International Supply Chain. A report prepared by the New Zealand Shippers' Council, an association of major cargo owners. No. 92.

Nimmo-Bell (2009). Economic Costs of Pests to New Zealand. MAF Biosecurity New Zealand Technical Paper No: 2009/31. Wellington, Ministry of Agriculture and Forestry. 79 p.

Notteboom, T.E. (2006). The time factor in liner shipping services. Maritime Economics & Logistics 8: 19-39.

OECD Maritime Transport Committee (2003). Cost Savings Stemming from Non-Compliance with International Environmental Regulations in The Maritime Sector. Paris, France, Organisation for Economic Co-operation and Development. 53 p.

Orams, M.B. (2002). Humpback whales in Tonga: An economic resource for tourism. *Coastal Management* 30: 361-380.

Pannell, A.; Coutts, A. (2007). Treatment methods used to manage *Didemnum vexillum* in New Zealand. A report prepared for Biosecurity New Zealand by the New Zealand Marine Faming Association Inc., 43 p.

Papatheodorou, A. (2006). The cruise industry: an industrial organizational perspective. In: Dowling, R.K. (ed) *Cruise Ship Tourism*, pp. 31-40, CABI Publishing, Oxfordshire, U.K.

Piola, R.F.; Conwell, C. (2010). Vessel biofouling as a vector for the introduction of nonindigenous marine species to New Zealand: Fishing vessels (Draft report). Prepared for MAF Biosecurity New Zealand Postclearance Directorate. Cawthron Institute, Nelson. 57 p.

PrimePort Timaru Ltd (2005). Report for year ended 30 June 2005. Timaru, PrimePort Timaru Ltd. 24 p.

Seafood Industry Council (2010). Charter Vessels. <http://www.seafoodindustry.co.nz/n1553,312.html>, Accessed 1/10/2010.

SSY Consultancy & Research Ltd (2001). The Cost to Users of Substandard Shipping. A report prepared for the OECD Maritime Transport Committee. Directorate for Science, Technology & Industry. 78 p.

Statistics New Zealand (2010a). Fish Monetary Stock Account 1996-2009. . Wellington, Statistics New Zealand. 53 p.

Statistics New Zealand (2010b). InfoShare. Overseas Cargo Statistics <http://www.stats.govt.nz/infoshare/>. Statistics New Zealand.

Takata, L.; Falkner, M.; Gilmore, S. (2006). Commercial Vessel Fouling In California:. Analysis, Evaluation, and Recommendations to Reduce Nonindigenous Species Release from the Non-Ballast Water Vector. California, California State Lands Commission, Marine Facilities Division. 76 p.

Thomas, K.V.; Brooks, S. (2010). The environmental fate and effects of antifouling paint biocides. *Biofouling* 26: 73-88

Thompson, G.A. (2004). Mechanisms of invasion and persistence of the invasive kelp *Undaria pinnatifida* (Harvey) Suringar within intertidal areas of southern New Zealand. PhD thesis. University of Canterbury. 166 p.

Tourism New Zealand (2007). 2006/07 Cruise Research. Understanding the New Zealand cruise experience. Wellington, Tourism New Zealand 22 p.

Tourism New Zealand (2010). Cruise Development: online publication at http://www.tourismnewzealand.com/delivering-the-promise/developing-the-tourism-industry/cruise-development.

U.S. Army Corps of Engineers (1987a). Underwater cleaning of concrete and steel: High-pressure water jets. REMR Technical Note CS-ES-3.5. Washington D.C., U.S. Army Corps of Engineers: Repair-evaluation-Maintenance-Rehabilitation Research Programme. 4 p.

U.S. Army Corps of Engineers (1987b). Underwater cleaning of concrete and steel: Powered Hand Tools. REMR Technical Note CS-ES-3.3. Washington D.C., U.S. Army Corps of Engineers: Repair-evaluation-Maintenance-Rehabilitation Research Programme. 4 p.

U.S. Army Corps of Engineers (1987c). Underwater cleaning of concrete and steel: self propelled vehicles. REMR Technical Note CS-ES-3.7. Washington DC, U.S. Army Corps of Engineers: Repair-evaluation-Maintenance-Rehabilitation Research Programme. 4 p.

UMR Research Ltd (2006). Marine Market Research: a Quantitative Study. 81 p.

Wijga, A.; Erdtsieck, E.; Romeeijn, J.; Berbee, R.; Tiesnitsch, J.; Rotteveel, S.; Eibrink, L. (2008). Biocide free 'antifouling' for ships: Emissions from the underwater coating 'Ecospeed' (English translation). . EU LIFE Project ECOTEC-STC Task 7.3. LIFE06 ENV/B/000362. 33 p.

Woods, C.; Floerl, O.; Fitridge, I.; Johnston, O.; Robinson, K.; Rupp, D.; Davey, N.; Rush, N.; Smith, M. (2007). Efficacy of hull cleaning operations in containing biological material: II Seasonal variability. MAF Biosecurity New Zealand Technical Paper Series No. 08/11 116 p.

Wotton, D.; O'Brien, C.; Stuart., M.; Fergus, D. (2004). Eradication success down under: heat treatment of a sunken trawler to kill the invasive seaweed *Undaria pinnatifida*. *Marine Pollution Bulletin* 49: 844-849.

Appendices

APPENDIX 1. MODELING THE PROBABILITY OF SPAWNING

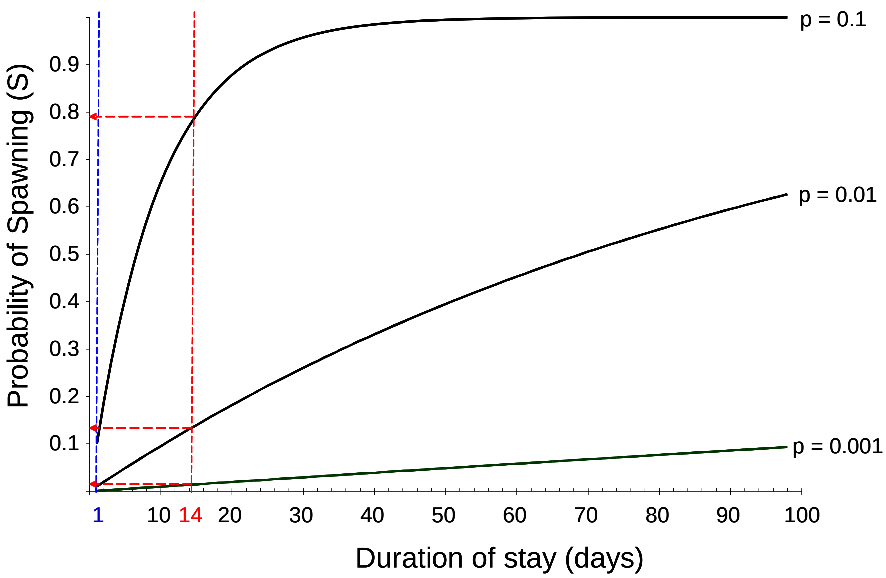
Although we cannot quantify the probability that biofouling organisms present on a vessel will spawn while the vessel is in New Zealand, the influence of duration of visit can be modelled. For example, if it can be assumed that the probabilities that spawning will occur on any single day that the vessel is present are independent, then the total probability that spawning will occur (*S*) can be modeled as the complement of the probabilities that spawning will not occur on any day during the visit, such that:

$$S(N) = 1-(1-p)^N$$

where *p* is the probability that spawning occurs on any single day and *N* is the number of days that the vessel is present in New Zealand waters. Similar functions have been used to model the probability of establishment of aquatic invaders spread by recreational vessels (Floerl et al. 2009a; Leung et al. 2004).

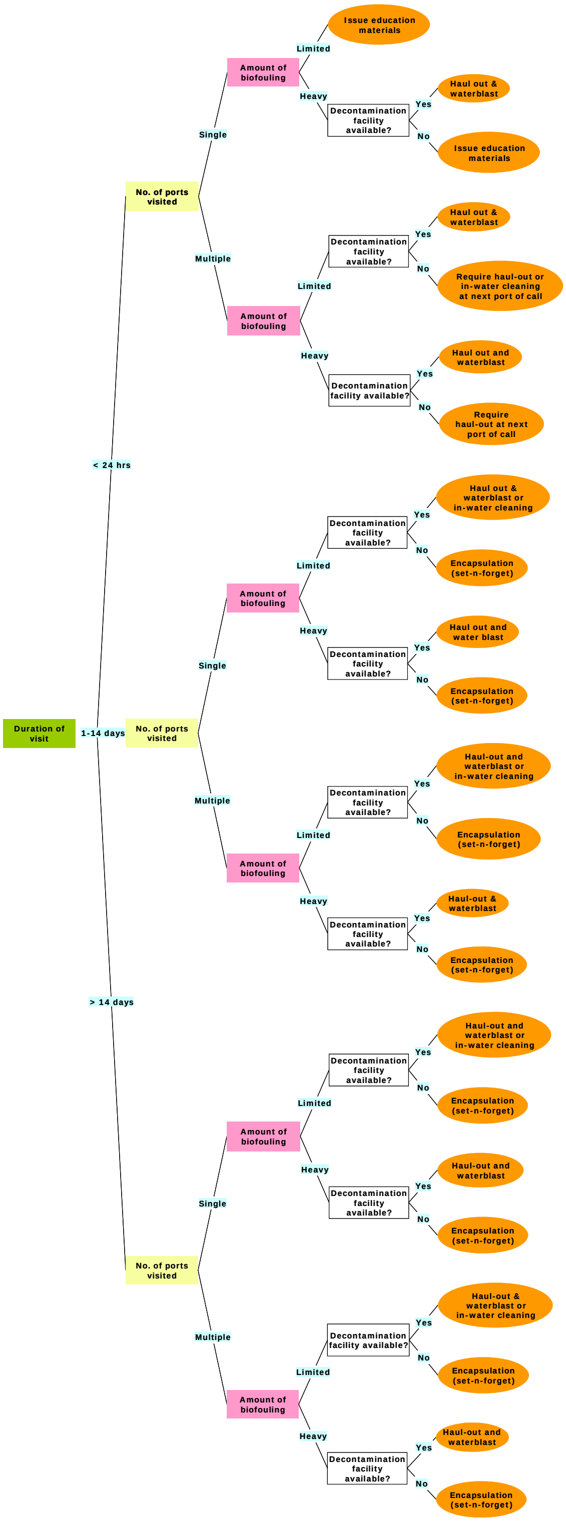
As seen in Figure 5, the relative risks presented by the scenarios considered in this project (i.e. <1 day, 1-14 days, >14 days turn-around) depend on the instantaneous probability of spawning, p. When p is large (e.g. p = 0.1) the difference in risk between the 1 day turn-around and the >14 day turnaround time is greatest. As p declines, so does the relative magnitude of difference between the scenarios.

Figure 5: Probability of spawning modelled as a simple function of the duration of stay in New Zealand. The broken lines depict the transition thresholds for the scenarios considered in this project.

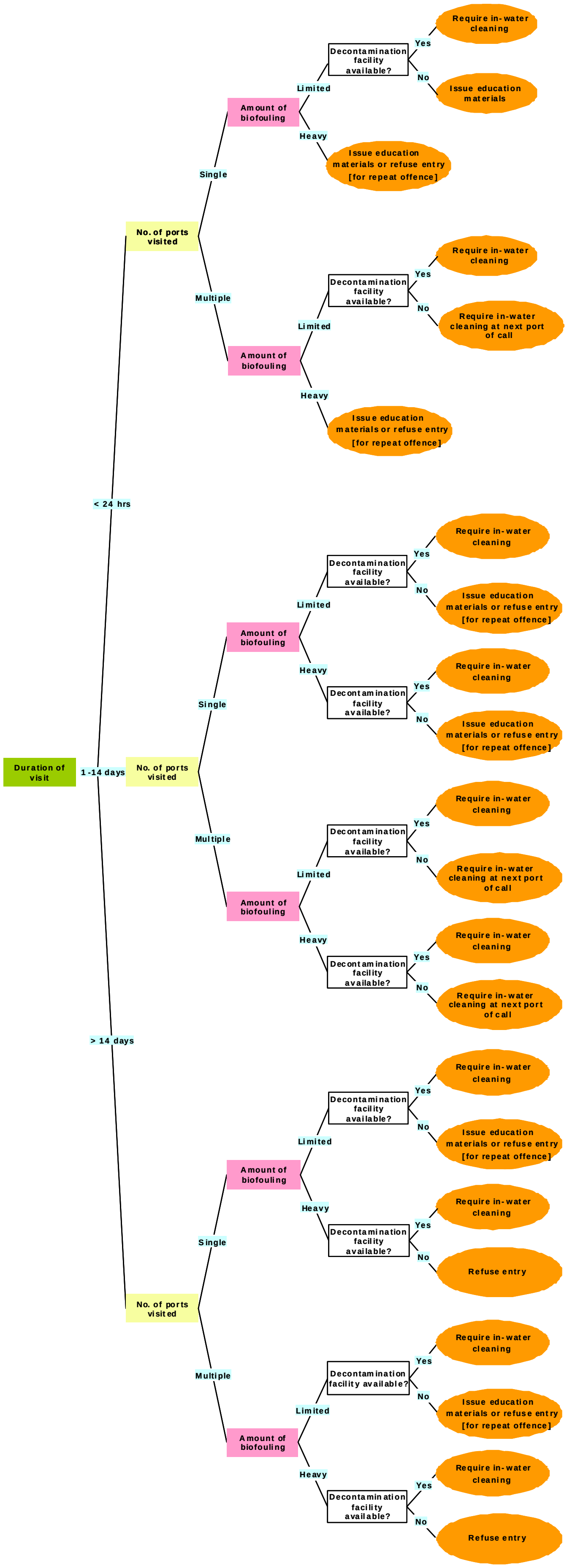


APPENDIX 2: DRAFT DECISION TREES FOR VESSELS THAT ARE NOT COMPLIANT WITH THE IMPORT HEALTH STANDARD FOR VESSEL BIOFOULING

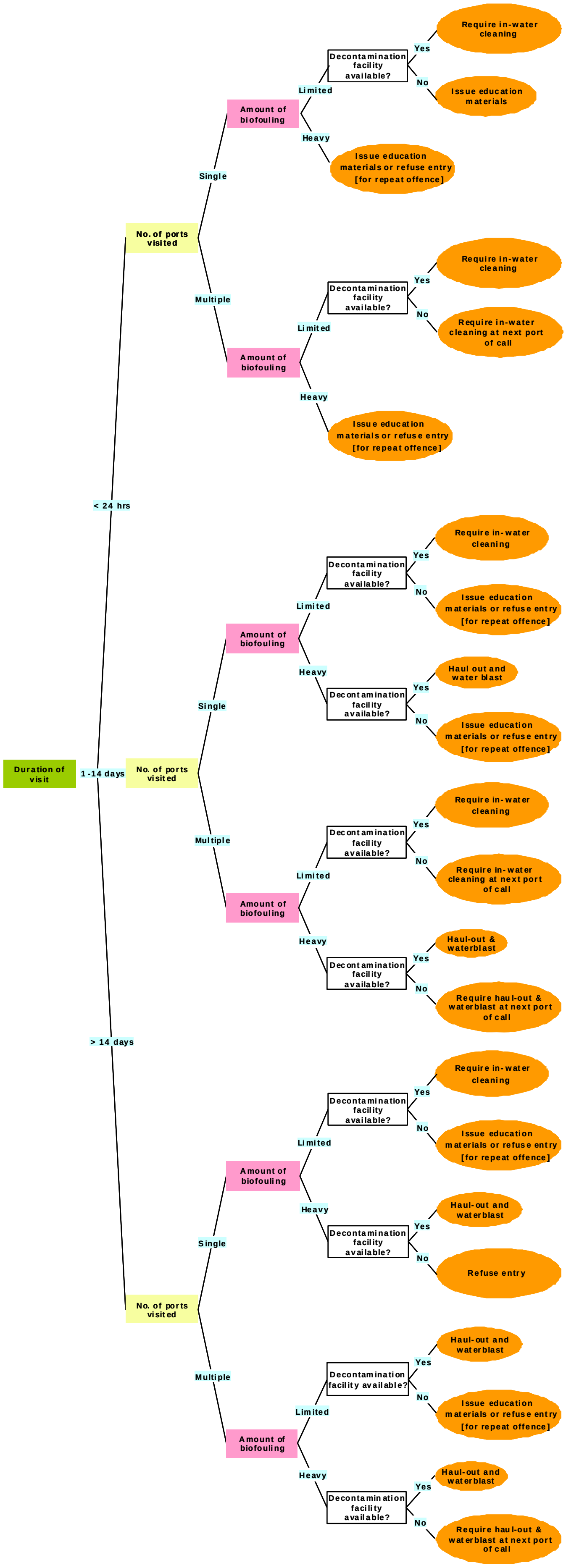
Recreational vessels



Passenger vessels



Fishing vessels



Merchant vessels