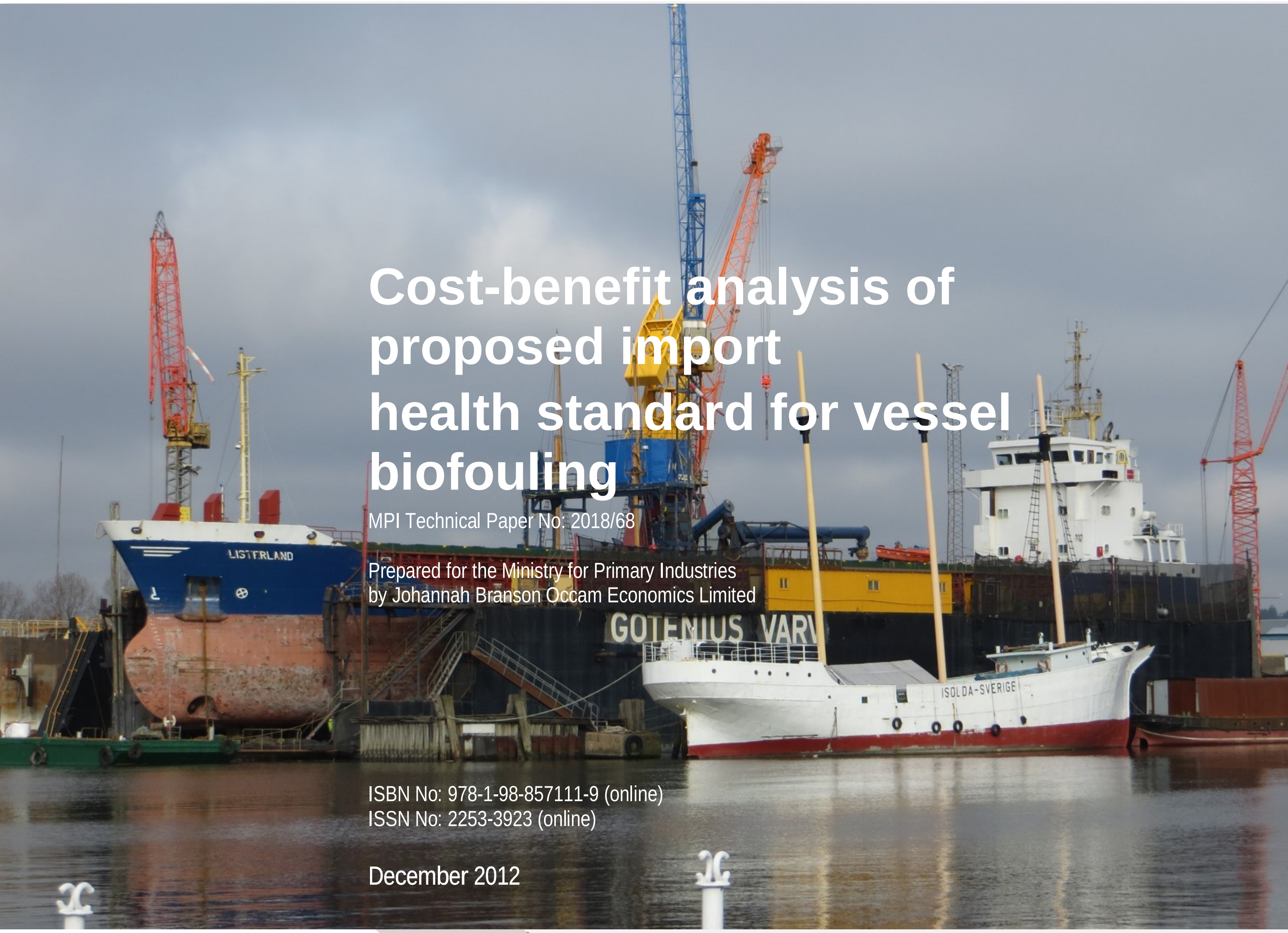
Biosecurity New Zealand

Tiakitanga Pūtaiao Aotearoa



Cost-benefit analysis of proposed import health standard for vessel biofouling

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Summary

The Ministry for Primary Industries (MPI) is proposing to adopt an import health standard (IHS) for biofouling on vessels from all countries. The proposed IHS would set requirements for the management of risks associated with biofouling on the submerged and occasionally submerged surfaces of vessels arriving in New Zealand. MPI commissioned an analysis of the costs and benefits of the proposed IHS. This report presents the method and results of this cost-benefit analysis (CBA).

Method

MPI advises that if it did not proceed with the proposed IHS, the risks to New Zealand posed by the introduction of new non-indigenous marine species as biofouling on vessels are such that it would still consider some form of intervention necessary. MPI advises that the minimum intervention would most likely be the development and promotion of a voluntary standard to encourage good biofouling management. This CBA therefore assesses the costs and benefits of the proposed IHS relative to the baseline scenario of this voluntary standard.

New Zealand is not the only country considering adopting standards to reduce risks from vessel biofouling. This CBA therefore assess the costs and benefits of the proposed IHS under each of two international scenarios:

- voluntary standards in Australia and California or
- mandatory standards in Australia and California.

Both the proposed IHS and the voluntary standard would incur additional costs to government and the owners and operators of vessels arriving in New Zealand:

- border process costs – for submitting biofouling declarations, undertaking investigations and issuing warnings or directing vessels to take action to mitigate their biofouling risks
- compliance costs – for vessels that improve their biofouling management to comply with the standard and
- action costs – for non-compliant vessels that are directed to take action to mitigate their biofouling risks.

MPI modelled vessel compliance rates and action rates, by vessel type, under each scenario, for use in this CBA.

The objective of both the proposed IHS and the voluntary standard would be, through improving vessel biofouling management, to reduce in the rate of introduction of new nonindigenous marine species to New Zealand. To the extent that these species could enter and establish in New Zealand and impact on the country's economy, environment and/or health and well-being of its people, the introduction of even one less species may deliver a wide range of benefits in avoiding the potential impacts of this species on:

- initial incursion response
- aquaculture
- commercial fishing
- coastal infrastructure
- marine tourism and recreation
- recreational fishing
- recreational shellfish gathering
- recreational use of beaches
- human health and
- indigenous biodiversity.

Improved management of biofouling to comply with the proposed IHS or the voluntary standard may also provide incidental benefits in improving vessel fuel efficiency.

For use in this CBA, MPI also modelled rates of introduction of non-indigenous marine species, not previously known to be in New Zealand, under each scenario.

Results

The results of this CBA suggest that, over timeframes of between 10 and 50 years from 2013, the additional benefits of the proposed IHS in avoiding the impacts of introduced species on affected sectors would be sufficient to outweigh the additional costs incurred in improving biofouling management, relative to the baseline scenario's voluntary standard. Even within the first 10 years of the proposed IHS, sufficient additional benefits would accrue to cover the additional costs accumulated over these years.

In total over the 50 years 2013 to 2062 inclusive, the proposed IHS is estimated to deliver additional net benefits of between $520 million under the scenario of mandatory standards in Australia and California and $865 million under the scenario of voluntary standards in Australia and California (in terms of present value in 2012). For each additional dollar of cost incurred, the proposed IHS is estimated to deliver around $23 to $25 in additional benefits by this time.

Figure S1 Additional present value total costs and benefits of proposed IHS relative to voluntary standard – Scenario V (voluntary standards in Australia and California)
In 2012 prices and present values

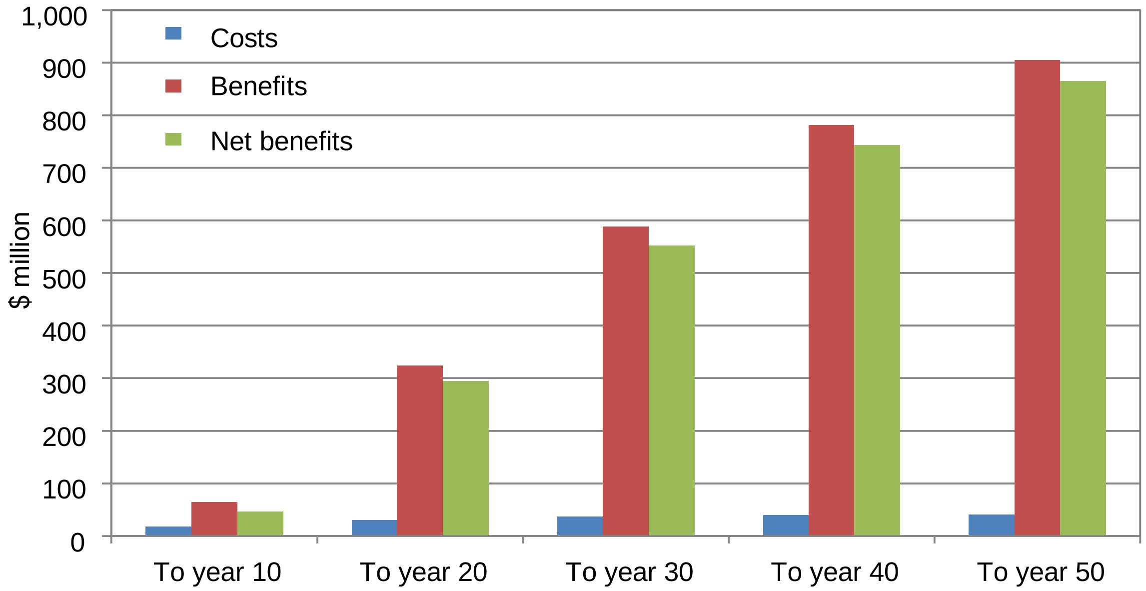
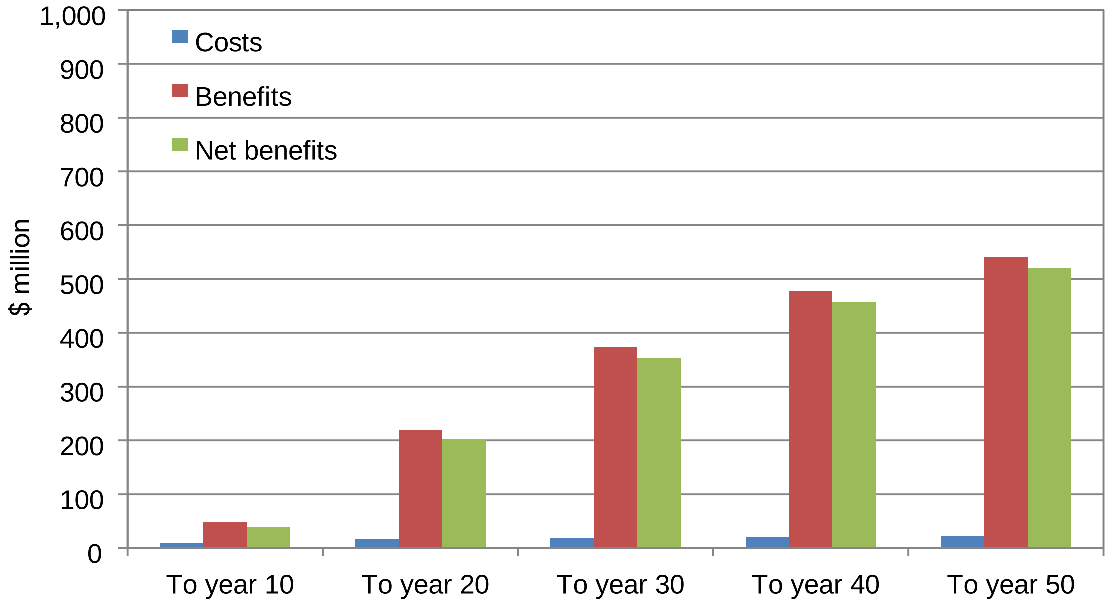


Figure S2 Additional present value total costs and benefits of proposed IHS relative to voluntary standard – Scenario M (mandatory standards in Australia and California)
In 2012 prices and present values



The largest component (77% to 83%) of the estimated additional costs of the proposed IHS is the costs to non-compliant vessels directed to take action to mitigate their biofouling risks. Of the estimated additional compliance and action costs to vessels, around 95% fall on freight vessels. This is partly because freight vessels account for three-quarters of vessel arrivals per year, but also because non-compliant freight vessels are modelled as having the highest action costs per vessel, from the disruption to their ability to deliver and pick up freight if directed to leave New Zealand.

Application of elasticities of demand suggests that the additional costs to freight and cruise vessels improving their biofouling management to comply with the proposed IHS would be unlikely to have much effect on the demand for freight vessel services and cruises. Additional costs to non-compliant freight and cruise vessels directed to take action to mitigate their biofouling risks would be larger and could significantly affect demand for the services of these vessels, but would be unlikely to translate into a reduction in demand across the industry, given that these vessels would be few in number.

By far the largest component (90%) of the estimated additional benefits of the proposed IHS is the avoided impacts of introduced species on the aquaculture sector, particularly Greenshell mussels, given its vulnerability to most of the species that could be introduced by vessel biofouling. This is followed by avoided impacts on recreational fishing (3.0%) and recreational use of beaches (2.7%), given the popularity of these activities.

Table S1 Distribution of additional present value total costs and benefits of proposed IHS relative to voluntary standard to year 50
$ million, in 2012 prices and present values, over 2013 to 2062

	Scenario V		Scenario M	
Costs				
Compliance	9.2	23%	3.7	17%
Action	31.0	77%	17.8	83%
Total costs	40.2		21.5	
Benefits				
Initial incursion response	2.0	0.2%	0.8	0.2%
Aquaculture	815.7	90%	488.7	90%
Commercial fishing	15.5	1.7%	9.4	1.7%
Coastal infrastructure	0.3	0.03%	0.2	0.03%

Marine tourism and recreation	5.7	0.6%	3.5	0.6%
Recreational fishing	26.9	3.0%	16.3	3.0%
Recreational shellfish gathering	3.1	0.3%	1.9	0.3%
Recreational use of beaches	24.1	2.7%	14.6	2.7%
Indigenous biodiversity	6.9	0.8%	4.2	0.8%
Vessel fuel efficiency	4.6	0.5%	1.9	0.3%
Total benefits	904.8		541.6	
Total net benefits	**864.6**		**520.1**	

Notes: not modelled in this CBA are border process costs, which MPI considers unlikely to be significant or more than minor, and human health benefits, given that the other benefits modelled incorporate responses of affected sectors to avoid or reduce adverse impacts on human health

Many of the inputs used in modelling these costs and benefits are, inevitably, somewhat uncertain at this time. Experience of the proposed IHS over its initial four year voluntary period may provide more accurate information on its impacts before it is made mandatory. In the meantime, sensitivity analysis suggests that the CBA's results are reasonably robust to adoption of lower or higher values for each of the costs and benefits modelled. Although their magnitude is affected, the additional net benefits of the proposed IHS remain positive and substantial throughout. Even with all of the costs 25% higher and all of the benefits 25% lower than modelled, the proposed IHS is still indicated to provide substantially higher net benefits than the baseline scenario's voluntary standard. The additional net benefits of the proposed IHS are most sensitive to vessel action rates, the rates of introduction and spread of species that could be introduced by vessel biofouling, how severely these species might affect aquaculture production and the rate of growth in the aquaculture sector.

In conclusion, contingent on the vessel compliance and action rates and species introduction rates modelled by MPI, this CBA suggests that we can be confident that the proposed IHS would deliver substantially higher net benefits to New Zealand than the alternative of a voluntary standard.

Contents

Page

1 Purpose

The Ministry for Primary Industries (MPI) is proposing to adopt an import health standard (IHS) for biofouling on vessels from all countries (Ministry of Agriculture and Forestry, 2012a and 2012b). The proposed IHS would set requirements for the management of risks associated with biofouling on the submerged and occasionally submerged surfaces of vessels arriving in New Zealand.

MPI commissioned Occam Economics to provide an analysis of the costs and benefits of the proposed IHS. In this report, we present the method and results of this cost-benefit analysis (CBA). The purpose of this CBA is to test whether the proposed IHS would provide greater net benefits than the alternative. The purpose of this report is to document how we modelled these costs and benefits.

2 Method

2.1 CBA process

CBA provides a formal, structured method for systematically assessing proposals in terms of their outcomes relative to their use of resources.

The CBA process typically comprises 10 steps:

1. define the problem
2. select the proposal/options for assessment
3. specify the baseline scenario
4. identify the impacts of the proposal/options – positive (benefits) and negative (costs)
5. where possible, quantify the impacts
6. where possible, value the impacts
7. adjust for differences in the timing of the impacts
8. calculate decision criteria
9. analyse the sensitivity of the results and
10. document the CBA.

We apply each of these 10 steps in constructing a CBA of the proposed IHS. This follows the standard CBA methodology for biosecurity incursion responses set out in Ministry of Agriculture and Forestry (2002) and applied in numerous economic impact assessments prepared by or for MPI (e.g. painted apple moth, red imported fire ant, pine pitch canker, Didymosphenia geminata). As in all CBAs, it is necessary to exercise pragmatism in the complexity and depth of analysis undertaken, according to what is feasible within the data and time constraints and useful to informing policy development and decisions.

2.2 Problem definition and proposal

Biofouling is the accumulation of organisms, including aquatic microorganisms, algae, plants and animals, on surfaces immersed in sea water. Like the discharge of vessel ballast water, biofouling on vessel hulls can inadvertently transfer organisms from one location to another. Whilst the ballast water IHS (Ministry of Agriculture and Forestry, 2005) has reduced the risk of entry via ballast water, vessel biofouling has remained an important pathway for the introduction of non-indigenous marine organisms into New Zealand's territorial waters (Ministry of Agriculture and Forestry, 2011a). MPI has been investigating ways to reduce the risks to New Zealand posed by the introduction of non-indigenous species as biofouling on vessels, whilst facilitating international trade and efficient clearance of vessels at the border.

The International Maritime Organization (IMO) recently adopted guidelines for the control and management of vessel biofouling to minimise the transfer of invasive aquatic species (International Maritime Organization, 2011a). These guidelines reinforce the importance of the maritime transport sector taking responsibility for managing the risks generated by its activities. MPI also already has a communications programme to encourage vessel cleaning and antifouling, targeted at international yachts and slow moving/specialist vessels (especially in the oil exploration industry), which have been found to have higher levels of biofouling than other vessel types.

Given the limited effectiveness of voluntary measures, however, MPI is proposing to impose mandatory requirements through a vessel biofouling IHS, under Section 22 of the Biosecurity Act 1993 (Ministry of Agriculture and Forestry, 2012a and 2012b). The proposed IHS would set requirements for the management of risks associated with biofouling on the submerged and occasionally submerged surfaces of all types of vessels arriving in New Zealand from all countries.

The primary requirement would be for vessels to arrive with "clean" hulls, where "clean" is defined as no biofouling beyond the "allowances" (maximum thresholds) specified in the IHS.
A clean hull could be achieved through ongoing good hull maintenance (application/installation and regular maintenance of appropriate antifouling coatings/systems to a high standard) and/or cleaning shortly before the voyage to New Zealand. Vessel owners or operators would be responsible for ensuring that vessels arrive clean. They would be required to submit a declaration on each vessel's voyage history, operating profile and biofouling management, which would be used to assess its biofouling risk, and, if requested, to produce documentary evidence to allow verification of the declaration. Operating to an agreed biofouling management plan and demonstrating compliance in a biofouling record book, preferably in a format consistent with IMO guidelines (templates available at International Maritime Organization, 2011b), would expedite this process.

Vessels arriving without satisfactory documentary evidence and/or suspected of having biofouling above the applicable allowances may be subject to investigation, which could include examining documents, interviewing crew and/or inspecting hulls. Where this finds non-compliant biofouling or insufficient evidence of adequate biofouling management, vessels may be given warnings or directed to take action to mitigate their biofouling risks. Under the latter, MPI may direct vessels to be defouled or to have their biofouling treated by an agreed method, restrict the locations or durations of visits or direct vessels to leave New Zealand as soon as practicable.

To allow vessel owners and operators time to incorporate improved biofouling management into their routine hull maintenance, MPI proposes that the IHS be voluntary for the first four years. During this voluntary period, vessels found to have biofouling above the applicable allowances may be given warnings, but MPI expects that generally only recreational vessels would be directed to take action to mitigate their biofouling risks.

For modelling purposes, we assume that the proposed IHS would come into effect from the beginning of 2013, with the voluntary period spanning the calendar years 2013 to 2016 inclusive, and become mandatory from the beginning of 2017.

2.3 Baseline scenario

A critical step in any CBA is specifying the appropriate baseline scenario. This represents the default or prevailing situation or conditions that would occur, or are most likely, in the absence of the proposal under consideration. It is relative to this counterfactual that the costs and benefits of the proposal are measured.

There are generally three types of baseline scenario. The first is "no intervention" to address the problem. This is applicable for problems where there is no intervention currently and the decision-maker could feasibly choose not to intervene in any way. The second is the "status quo", which is the continuation of the existing intervention. This is applicable where there is already an intervention in place to address the problem and this is likely to be retained unless an explicit decision is made to end this intervention. In this case, the question that the
CBA is intended to help inform is whether to alter, augment, replace or cease this intervention. The third is the "minimum intervention", represented by the lowest feasible and realistic level of intervention. This is applicable where the nature or magnitude of the problem is such that it would not be feasible or acceptable to choose not to intervene. In this case, the question that the CBA is intended to help inform is whether to intervene more than this minimum level.

MPI advises that if it did not proceed with the proposed IHS, the risks to New Zealand posed by the introduction of non-indigenous species as biofouling on vessels are such that it would still consider some form of intervention necessary. MPI advises that the minimum intervention would most likely be the development and promotion of a voluntary standard to encourage good biofouling management.

Under this voluntary standard, arriving vessels would still be required to submit a biofouling declaration and may be subject to investigation. Vessels found to have severe biofouling may be given warnings, but MPI expects that generally only severely fouled recreational vessels would be directed to take action to mitigate their biofouling risks.

For the purpose of assessing the proposed IHS, we define the baseline scenario as this voluntary standard, taking effect from the beginning of 2013. We therefore assess the extent to which the proposed IHS would incur additional costs and deliver additional benefits beyond those that would occur under this voluntary standard.

2.4 International scenarios

New Zealand is not the only country considering adopting standards to reduce risks from vessel biofouling. Australia and the state of California, in particular, are also at advanced stages in developing proposals (PricewaterhouseCoopers, 2011, California State Lands Commission, 2012).

MPI therefore requested that this CBA assess the costs and benefits of the proposed IHS, relative to the baseline scenario of the voluntary standard, under each of two scenarios representing international developments:

- Scenario V – Australia and California both adopt voluntary standards for management of vessel biofouling or
- Scenario M – Australia and California both adopt mandatory standards for management of vessel biofouling.

The adoption of these standards would result in some improvement in biofouling management and reduction in risks to New Zealand to the extent that vessels visiting these jurisdictions and already complying with their standards also visited New Zealand.
Incorporating these international developments into the CBA therefore enables us to assess how much further the proposed IHS would improve biofouling management and reduce risks to New Zealand, and therefore cause additional costs and benefits, beyond what would already result from other jurisdictions' standards.

For modelling purposes, we assume that these standards would come into effect from the beginning of 2014.

2.5 Impacts

The next three steps in the CBA process are to identify and, to the extent feasible and useful, quantify and value the impacts of the proposal relative to the baseline scenario.
These impacts encompass the main consequences and implications of the proposal, given the likely responses of affected sectors – negative (costs) and positive (benefits), short-run and long-run, direct and indirect, intended and inadvertent – in terms of specific outcomes relative to the baseline scenario.

In the analysis of government policy, CBA is normally undertaken from a national economy perspective, weighing up the relative costs and benefits to New Zealand as a whole. Wealth transfers between parties, although affecting the distribution of costs and benefits, cancel each other out in the aggregation of total costs and benefits to New Zealand (i.e. where a cost to one party is an equivalent benefit to another party).

In the first instance, both the proposed IHS and the baseline scenario's voluntary standard may incur some implementation costs to government, such as in developing the standard, publicising and promoting the standard, developing border process protocols and training biosecurity inspectors. We do not model these costs explicitly as they are expected to be broadly similar under each of the proposed IHS and the voluntary standard.

Once implemented, both the proposed IHS and the voluntary standard would incur additional costs to government and the owners and operators of vessels arriving in New Zealand:

- border process costs – for submitting biofouling declarations, undertaking investigations and issuing warnings or directing vessels to take action to mitigate their biofouling risks

- compliance costs – for vessels that improve their biofouling management to comply with the standard and
- action costs – for non-compliant vessels that are directed to take action to mitigate their biofouling risks.

The objective of both the proposed IHS and the voluntary standard would be, through improving vessel biofouling management, to reduce in the rate of introduction of nonindigenous species to New Zealand. To the extent that these species could enter and establish in New Zealand and impact on the country's economy, environment and/or health and well-being of its people, the introduction of even one less species may deliver a wide range of benefits in avoiding the potential impacts of this species on:

- initial incursion response
- aquaculture
- commercial fishing
- coastal infrastructure
- marine tourism and recreation
- recreational fishing
- recreational shellfish gathering
- recreational use of beaches
- human health and
- indigenous biodiversity.

Improved management of biofouling to comply with the proposed IHS or the voluntary standard could also provide incidental benefits in improving vessel fuel efficiency.

We outline below, in turn, how we model each of the above costs and benefits. Many of the inputs used in this modelling are, inevitably, somewhat uncertain at this time. Experience of the proposed IHS over its initial four year voluntary period may provide more accurate information on its impacts before it is made mandatory.

All monetary values are expressed in New Zealand dollars at 2012 prices, unless indicated otherwise.

2.6 Costs

There are three main components in modelling the costs of the proposed IHS relative to the baseline scenario of a voluntary standard:

- the total number of vessels arriving in New Zealand each year • how many of these vessels would:
    - o be subject to border processes
    - o improve their biofouling management to comply with the standard o of non-compliant vessels, be directed to take action to mitigate their biofouling risks and
- the costs per vessel of:
    - o border processes
    - o compliance with the standard
    - o action directed to mitigate biofouling risks.

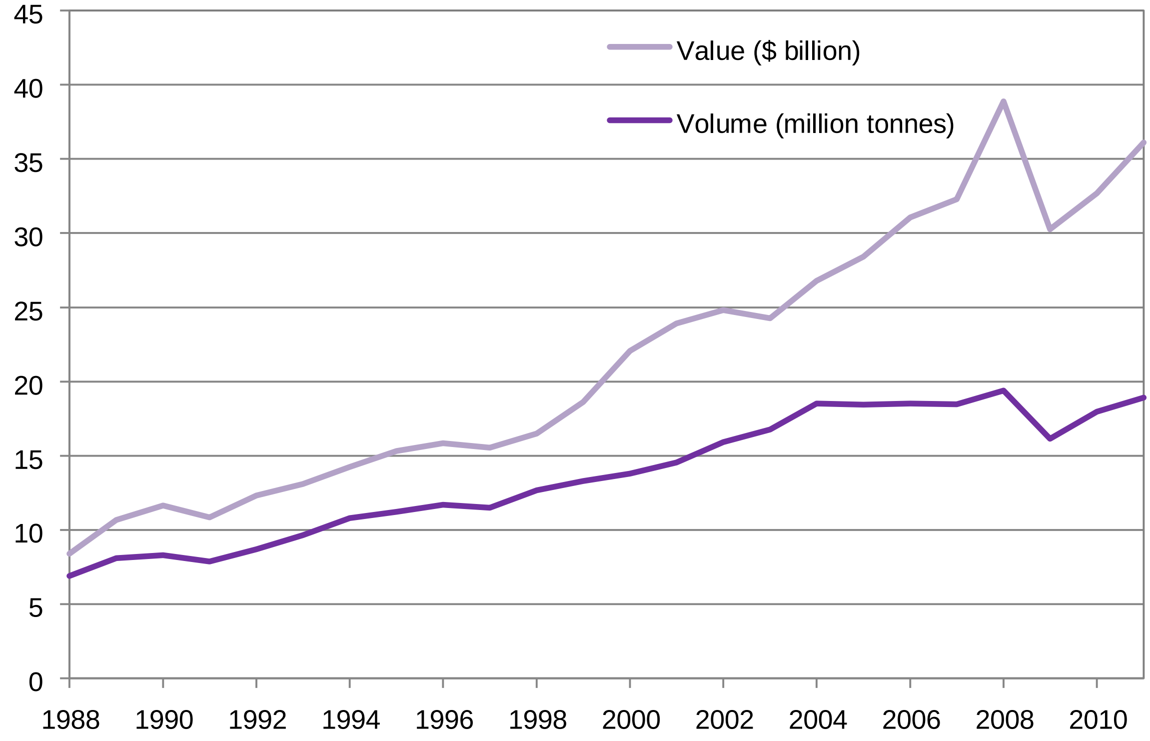
We model these costs separately for each type of vessel, given that rates of compliance and action, as well as compliance and action costs per vessel, would be likely to differ significantly by vessel type.

2.6.1 Number of vessels

Over 3,000 vessels arrive in New Zealand each year. By type of vessel, arrival numbers fluctuate significantly year to year (by as much as 20% is not uncommon).

Around the world, international trade dropped sharply in 2009 with the global economic downturn that followed the global financial crisis. For New Zealand, the volume of imports by sea has yet to recover to previous levels, as shown in Figure 1. This drop in import volumes affected not just vessel numbers but also vessel sizes, such that vessel arrivals data from 2009 may not be representative.

Figure 1 New Zealand imports by seaports per year
Year to December, current prices



Source: Statistics New Zealand (2012a)

In estimating the costs of the proposed IHS relative to the baseline scenario of a voluntary standard, we therefore use the average annual number of vessel arrivals over the three years 2006 to 2008, shown in Table 1.

Table 1 Average number of vessel arrivals per year
2006 to 2008, year to December

Vessel Type	**Number**
Container	1,319
Bulk	459
General cargo	223
Tanker	316
Other commercial (roll on-roll off)	190
Cruise	86
Fishing	73
Recreational (yachts)	625
Slow moving/specialist	86
Total	3,349

Source: Obtained by MPI from New Zealand Customs Service, May 2012
Notes: 2008 data not available for recreational vessels and slow moving/specialist vessels – table shows average over 2005 to 2007
These data include multiple arrivals by vessels that visit New Zealand more than once. For example, although most recreational vessels visit New Zealand only once within any given year, container ships visit, on average, seven times each per year. Adjusting for multiple arrivals by the same vessel, Table 2 shows the average annual number of arrivals by
"unique" vessels over the same period.

Table 2 Average number of unique vessel arrivals per year
2006 to 2008, year to December

Vessel Type	Number
Container	187
Bulk	230
General cargo	74
Tanker	140
Other commercial	56
Cruise	30
Fishing	56
Recreational	623
Slow moving/specialist	60
Total	1,226

Source: Obtained by MPI from New Zealand Customs Service, May 2012
Notes: 2008 data not available for recreational vessels and slow moving/specialist vessels – table shows average over 2005 to 2007

2.6.2 Border process costs

Under both the proposed IHS and the voluntary standard, there would be three main steps in the border process for vessels arriving in New Zealand:

- declaration – all vessels arriving in New Zealand would be required to submit a declaration on voyage history, operating profile and biofouling management, which would be used to assess their biofouling risks
- investigation – based on biofouling risks, some vessels would be flagged for investigation, which may include examining documents, interviewing crew and/or inspecting hulls and
- warning or direction to take action – based on the findings of investigations, some vessels would be given warnings and some directed to take action to mitigate their biofouling risks.

Declaration

The requirement to submit a declaration would apply to all vessel arrivals.

We assume that submitting declarations would incur negligible additional costs to vessels, given that they already submit a range of information on or before arrival for the existing purposes of New Zealand's border agencies. To support this declaration, vessels should retain documentary evidence and maintain records on their biofouling management. We assume that these could also be done at negligible additional cost. This would be assisted by the initial four year voluntary period of the proposed IHS, to allow vessels time to incorporate improved biofouling management into their routine hull maintenance, including retaining certification and other supporting documents when treatments are undertaken. There may be some initial costs in developing a biofouling management plan and biofouling record book, specific to each vessel, but these could be minimised by using the IMO templates and/or integrating this plan into the vessel's existing operational and procedural records. Offsetting any such costs would be the benefits of time saved in submitting and verifying declarations.

MPI considers that assessing declarations would not incur significant additional costs to government beyond the time already spent by biosecurity inspectors on assessing arriving vessels for existing biosecurity purposes.

Investigation

Vessels arriving without satisfactory documentary evidence and/or suspected of having biofouling above the applicable allowances may be flagged for investigation. MPI advises that only vessels assessed as relatively high risk would be investigated.

Investigation may include examining documents, interviewing crew and, in some cases, inspecting hulls. We assume that, on average, investigations would incur negligible additional costs to vessels for crew members' time or vessel delays, given that investigations could be undertaken concurrently with the existing clearance processes of New Zealand's border agencies.

MPI considers that undertaking investigations would incur only minor additional costs to government and advises that these costs would be met from existing Crown funding through reprioritisation. These still represent additional costs to the extent that they divert funding from existing or alternative activities.

Warning or direction to take action

Based on the findings of investigations, some vessels would be given warnings and some directed to take action to mitigate their biofouling risks.

For vessels, receiving a warning would be unlikely, of itself, to incur a significant cost, but could result in additional costs if they respond to this warning by improving their biofouling management to become compliant with the proposed IHS or voluntary standard for subsequent visits. These compliance costs are the subject of Section 2.6.3 below. Similarly, of itself, being directed to take action is unlikely to incur a significant cost, but taking the action directed would incur additional costs. These action costs are the subject of Section 2.6.4 below.

For government, issuing a warning or directing a vessel to take action would be unlikely to add significantly to the amount of time required of biosecurity inspectors beyond that spent on declaration and investigation.

Total costs

Given that MPI considers the additional costs of these border processes unlikely to be significant or more than minor, we do not model any border process costs in this CBA.

2.6.3 Compliance costs

Compliance rates

To improve its ability to identify and manage biosecurity risks associated with international vessels, MPI has undertaken a programme of research to address the main knowledge gaps around vessel biofouling. This research programme included a survey of biofouling on international vessels arriving in New Zealand (Ministry of Agriculture and Forestry, 2010). This survey involved sampling biofouling on a range of vessel types and collecting and assessing information on these vessels, including maintenance regime and voyage history, to evaluate biofouling risk factors. Almost 60% of vessels in the sample were found to have biofouling with non-indigenous species, 30% with non-indigenous species not known to be established in New Zealand.

Based on the findings of this biofouling survey, MPI was able to calculate approximately what proportion of vessel arrivals, by vessel type, have biofouling below what would be the allowances of the proposed IHS and would therefore be considered "clean". We adopt this as indicative of compliance rates before the proposed IHS (in year 0, 2012).

The biofouling survey included some vessels sampled more than once over the survey period. MPI was able to isolate the findings for these vessels to examine the rate at which these vessels improved their biofouling management over time. MPI also used the biofouling survey data on vessels with biofouling above what would be the allowances of the proposed IHS or the baseline scenario's voluntary standard to derive the distribution of vessels according to amount of biofouling, for each vessel type. For the purpose of this CBA, MPI then used the amount of biofouling, combined with the frequency of routine hull maintenance, to model how readily vessels could improve their biofouling management and therefore how rates of compliance with the proposed IHS or the voluntary standard might increase over time, under each of the two international scenarios (voluntary or mandatory standards in Australia and California).

These compliance rates are shown in Table 3, where the proposed IHS or voluntary standard would come into effect from the beginning of year 1 (2013). MPI assumes that compliance rates would reach their upper limits in year 10 (2022) and remain constant thereafter. The biofouling survey did not include slow moving/specialist vessels – a diverse group, ranging from barges and dredges to naval vessels and drilling rigs for the oil industry – so MPI was unable to model compliance rates for this vessel type and excluded this vessel type from the CBA. We consider the effect of lower or higher compliance rates in the sensitivity analysis of Section 3.4 below. Experience of the proposed IHS over its initial four year voluntary period may provide more accurate information on the likely responses of vessel owners and operators.

Table 3 Compliance rates

Percentage of all vessel arrivals that are “clean”, rounded to the nearest whole percentage

Scenario V (voluntary standards in Australia and California)

Year	0 2012	1 2013	2 2014	3 2015	4 2016	5 2017	6 2018	7 2019	8 2020	9 2021	10+ 2022+
Baseline scenario (voluntary standard)											
Container	51%	52%	53%	56%	58%	60%	62%	64%	65%	67%	68%
Bulk	48%	49%	52%	55%	58%	60%	63%	65%	67%	69%	71%
General cargo	48%	49%	51%	53%	56%	59%	61%	63%	65%	66%	68%
Tanker	50%	50%	51%	52%	54%	55%	56%	57%	59%	60%	61%
Other commercial	47%	48%	50%	53%	56%	58%	61%	63%	65%	66%	68%
Cruise	47%	54%	59%	67%	72%	75%	77%	79%	80%	81%	81%
Fishing	50%	50%	51%	52%	53%	54%	55%	56%	57%	58%	59%
Recreational	35%	50%	70%	76%	76%	77%	77%	77%	77%	78%	78%
Slow moving/specialist											
Proposed IHS											
Container	51%	52%	55%	59%	62%	65%	68%	71%	73%	76%	78%
Bulk	48%	50%	53%	58%	62%	65%	69%	72%	75%	78%	80%
General cargo	48%	49%	52%	57%	61%	64%	67%	70%	73%	76%	78%
Tanker	50%	50%	52%	55%	58%	60%	63%	65%	68%	70%	72%
Other commercial	47%	49%	52%	57%	61%	64%	68%	71%	74%	77%	79%
Cruise	47%	54%	61%	70%	75%	79%	82%	85%	88%	90%	91%
Fishing	50%	50%	52%	55%	57%	59%	62%	64%	67%	69%	71%
Recreational	35%	50%	70%	76%	76%	81%	85%	85%	85%	85%	85%
Slow moving/specialist											

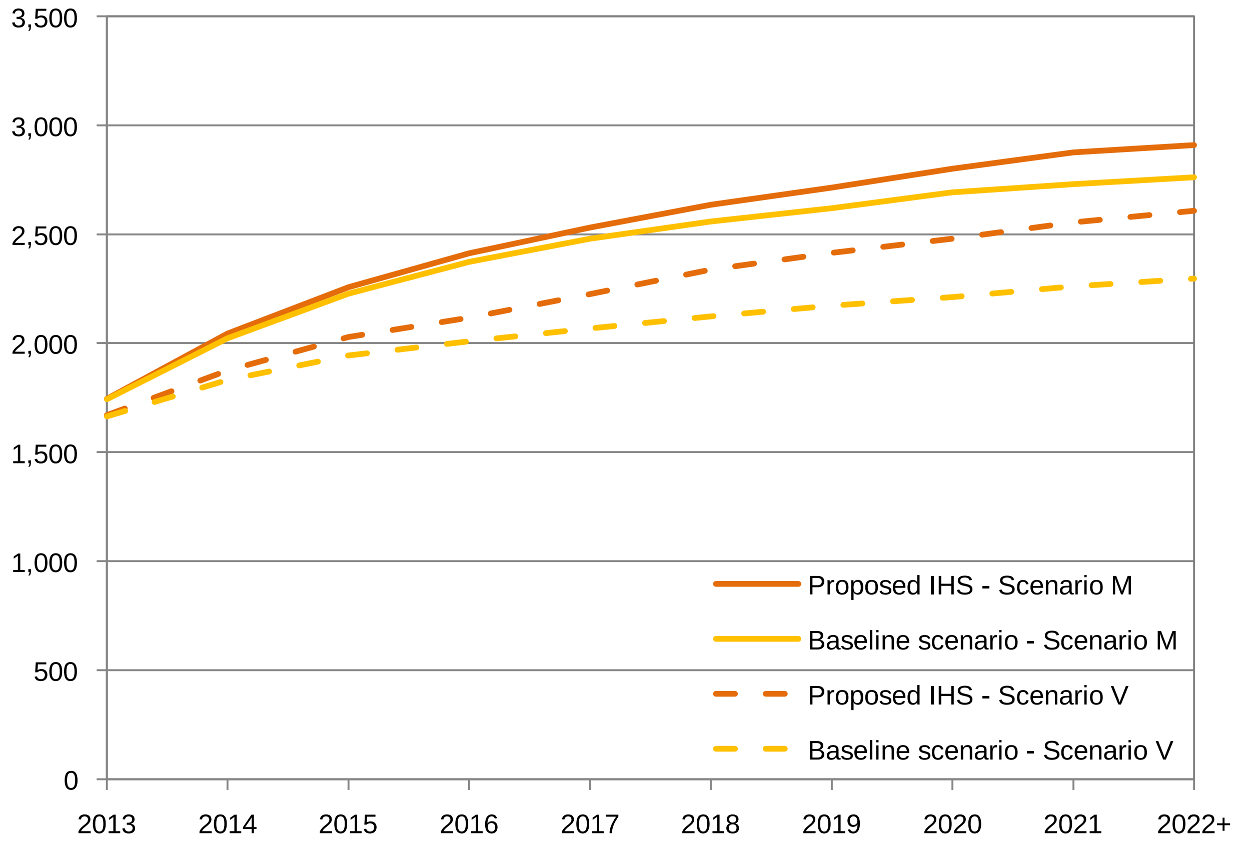
Scenario M (mandatory standards in Australia and California)

Year	0 2012	1 2013	2 2014	3 2015	4 2016	5 2017	6 2018	7 2019	8 2020	9 2021	10+ 2022+
Baseline scenario (voluntary standard)											
Container	51%	54%	58%	64%	69%	73%	76%	78%	81%	82%	83%
Bulk	48%	52%	58%	65%	72%	77%	80%	83%	86%	88%	89%
General cargo	48%	51%	56%	63%	68%	72%	76%	78%	80%	82%	83%
Tanker	50%	51%	54%	59%	63%	66%	69%	72%	75%	77%	79%
Other commercial	47%	50%	56%	63%	69%	73%	76%	78%	80%	81%	82%
Cruise	47%	57%	66%	76%	81%	84%	85%	87%	88%	89%	90%
Fishing	50%	51%	53%	57%	60%	63%	65%	67%	69%	71%	72%
Recreational	35%	54%	79%	85%	86%	86%	86%	86%	86%	86%	86%
Slow moving/specialist											
Proposed IHS											
Container	51%	54%	59%	65%	71%	75%	78%	81%	84%	87%	88%
Bulk	48%	52%	58%	66%	72%	77%	81%	84%	87%	90%	91%
General cargo	48%	51%	57%	64%	70%	75%	79%	82%	85%	87%	89%
Tanker	50%	51%	55%	60%	64%	68%	72%	75%	79%	82%	84%
Other commercial	47%	51%	57%	65%	71%	75%	79%	82%	85%	87%	89%
Cruise	47%	57%	68%	79%	84%	87%	89%	91%	93%	94%	95%
Fishing	50%	51%	54%	58%	61%	64%	66%	69%	71%	73%	75%
Recreational	35%	54%	79%	85%	86%	87%	89%	89%	90%	90%	90%
Slow moving/specialist											

Source: Modelled by MPI, June 2012

Applying these compliance rates to the average annual vessel arrival numbers of Table 1 gives the total number of compliant vessel arrivals shown in Figure 2.

Figure 2 Number of compliant vessel arrivals per year
Year to December



As shown in Figure 2, the number of compliant vessel arrivals would increase steadily over time as vessels responded to the proposed IHS or voluntary standard by improving their biofouling management when they became due for routine hull maintenance. This would be assisted by the four years notice of the proposed IHS becoming mandatory. The number of compliant vessel arrivals to New Zealand would be higher if Australia and California had mandatory standards (Scenario M) than if their standards were voluntary (Scenario V), to the extent that vessels arriving in New Zealand also visited these jurisdictions and already complied with their standards. Under both of these international scenarios, the proposed IHS would achieve higher compliance than the baseline scenario's voluntary standard. In assessing the costs of the proposed IHS relative to the baseline scenario, however, we are interested in the *difference* in compliance – how much *additional* compliance would be achieved by the proposed IHS than the voluntary standard. As can be seen in Figure 2, the proposed IHS would achieve a smaller addition to compliance if Australia and California had mandatory standards and make a greater difference if their standards were only voluntary.

Table 4 shows the additional compliance achieved by the proposed IHS (the difference between the proposed IHS and the voluntary standard).

Table 4 Additional compliance achieved by proposed IHS
Difference in percentage of all vessel arrivals that are "clean"

Year	0 2012	1 2013	2 2014	3 2015	4 2016	5 2017	6 2018	7 2019	8 2020	9 2021	10+ 2022+
Scenario V (voluntary standards in Australia and California)											
Container		0.0%	2.0%	3.0%	4.0%	5.0%	6.0%	7.0%	8.0%	9.0%	10.0%
Bulk		1.0%	1.0%	3.0%	4.0%	5.0%	6.0%	7.0%	8.0%	9.0%	9.0%
General cargo		0.0%	1.0%	4.0%	5.0%	5.0%	6.0%	7.0%	8.0%	10.0%	10.0%
Tanker		0.0%	1.0%	3.0%	4.0%	5.0%	7.0%	8.0%	9.0%	10.0%	11.0%
Other commercial		1.0%	2.0%	4.0%	5.0%	6.0%	7.0%	8.0%	9.0%	11.0%	11.0%
Cruise		0.0%	2.0%	3.0%	3.0%	4.0%	5.0%	6.0%	8.0%	9.0%	10.0%
Fishing		0.5%	1.5%	2.9%	4.0%	5.1%	6.4%	7.7%	9.1%	10.3%	11.4%
Recreational		0.0%	0.0%	0.0%	0.0%	4.0%	8.0%	8.0%	8.0%	7.0%	7.0%
Slow moving/specialist											
Scenario M (mandatory standards in Australia and California)											
Container		0.0%	1.0%	1.0%	2.0%	2.0%	2.0%	3.0%	3.0%	5.0%	5.0%
Bulk		0.0%	0.0%	1.0%	0.0%	0.0%	1.0%	1.0%	1.0%	2.0%	2.0%
General cargo		0.0%	1.0%	1.0%	2.0%	3.0%	3.0%	4.0%	5.0%	5.0%	6.0%
Tanker		0.0%	1.0%	1.0%	1.0%	2.0%	3.0%	3.0%	4.0%	5.0%	5.0%
Other commercial		1.0%	1.0%	2.0%	2.0%	2.0%	3.0%	4.0%	5.0%	6.0%	7.0%
Cruise		0.0%	2.0%	3.0%	3.0%	3.0%	4.0%	4.0%	5.0%	5.0%	5.0%
Fishing		0.1%	0.2%	0.4%	0.5%	0.7%	1.1%	1.5%	2.0%	2.5%	2.8%
Recreational		0.0%	0.0%	0.0%	0.0%	1.0%	3.0%	3.0%	4.0%	4.0%	4.0%
Slow moving/specialist											

Compliance costs per vessel

Commercial vessels already manage biofouling to some extent for existing reasons, such as safety, materials protection and fuel efficiency. This management typically comprises cleaning the hull and niche areas of any biofouling and re-applying antifouling coatings when vessels are hauled out or dry docked for routine maintenance, operating marine growth prevention systems on niche areas such as sea chests, and regularly inspecting hulls and niche areas and, if needed, spot cleaning between applications. The proposed IHS or voluntary standard would introduce an additional reason for biofouling management – to manage biosecurity risks – especially on parts of the vessel that may be less important to existing reasons for biofouling management, such as niche areas.

As shown in Table 3 above (for year 0), some vessels already have sufficiently good biofouling management to be considered “clean” under the proposed IHS or voluntary standard. We assume that these vessels would continue to do so and therefore face no additional compliance costs.

For vessels that are not already “clean”, becoming clean to comply with the proposed IHS or voluntary standard could be achieved by improving their biofouling management undertaken as part of routine hull maintenance and/or cleaning shortly before their voyage to New Zealand. Given the relative costs, as well as the four years notice of the proposed IHS becoming mandatory, MPI considers that, for most vessel types, the preferred way to become compliant would be to improve biofouling management as part of existing routine hull maintenance. Only for slow moving/specialist vessels, which make infrequent visits to New Zealand, does MPI consider that the preferred way to become compliant would be to clean before departure for New Zealand.

Biofouling management costs vary considerably by vessel type and size. The extent to which these costs would increase when biofouling management was improved to comply with the proposed IHS or voluntary standard would depend on the deficiency of current management.

Freight vessels

To optimise vessel performance, most freight vessels already have good biofouling management, including antifouling systems and regular inspections and spot cleaning. We model the additional cost to freight vessels becoming compliant with the proposed IHS or voluntary standard as that of improving their antifouling treatment or marine growth prevention systems in niche areas, where some biofouling may not significantly affect vessel performance but can carry biosecurity risks.

Costs of treatment

The full cost of applying antifouling coatings to freight vessels during routine hull maintenance ranges from around $126,000 per vessel weighing up to 5,000 tonnes to over $580,000 per vessel over 200 metres in length, taking five to seven days (NIWA, 2011, converted to New Zealand dollars using Reserve Bank of New Zealand, 2012, and updated to 2012 prices using Statistics New Zealand, 2012b).

We weight these costs and time requirements by the approximate size distribution of vessels visiting New Zealand (based on NIWA, 2011) to derive a weighted average cost and time per vessel, for each of the five types of freight vessel.

Assuming that around half the full cost and time per vessel is for treating the hull and half for niche areas, and that vessels becoming compliant with the proposed IHS or voluntary standard would need to increase treatment of niche areas by, on average, around 25% of this to reduce biofouling to within the allowances, implies average additional treatment costs per vessel becoming compliant of between around $44,000 for general cargo to around $69,000 for other commercial vessels, taking an additional 0.75 of a day for bulk and general cargo vessels to 0.9 of a day for other commercial vessels, on average.

Opportunity costs of time required

The additional time required for this treatment would have opportunity costs in that it would reduce the amount of time the vessel was available to earn revenue. As this would be additional time spent in port, following Kite-Powell and Hoagland (2002), we value it in terms of the revenue forgone net of operating costs saved (e.g. fuel). Revenue per vessel varies widely. We use average daily time charter rates plus a 20% margin (as used by PricewaterhouseCoopers, 2011) as indicative of average revenue per day. In so doing, we weight daily time charter rates (from NIWA, 2011, except general cargo from PricewaterhouseCoopers, 2011, converted to New Zealand dollars and updated to 2012 prices) by the approximate size distribution of vessels (based on NIWA, 2011) to derive a weighted average revenue per day for each of the five types of freight vessel. We also discount this average revenue by 50% to reflect that this additional time in port would be planned, added to when the vessel was already out of service for routine maintenance, so likely to be scheduled for an off-peak time or when the opportunity costs were low. The resulting average opportunity costs per vessel per day of additional time required range from $5,500 for bulk vessels to $12,000 for general cargo vessels and $14,000 for container vessels.

Total costs

Modern antifouling coatings have an effective life of at least five years and application can be incorporated into the five year hull maintenance and classification survey cycle of most freight vessels. The additional costs of improved antifouling of niche areas would therefore be incurred only every five years. Table 5 shows the average additional costs per vessel per year for vessels improving their antifouling of niche areas to comply with the proposed IHS or voluntary standard (e.g. for general cargo vessels, around $44,000 for improved antifouling treatment, taking around 0.75 of a day at $12,000 per day in opportunity costs, spread over five years). We do not include any additional travel costs given that this improvement in antifouling treatment would be undertaken at the times when, and locations where, vessels were already out of the water for existing routine maintenance.

Table 5 Average additional costs per vessel per year of improved antifouling of niche areas – freight vessels
$, in 2012 prices

Vessel type	Costs of treatment	Opportunity costs of time required	Total costs
Container	11,250	2,275	13,525
Bulk	10,013	825	10,838
General cargo	8,750	1,800	10,550
Tanker	12,500	2,031	14,531
Other commercial	13,750	2,188	15,938

Finally, in applying these compliance costs per vessel per year to the additional vessel arrival compliance rates of Table 4, we adjust for multiple arrivals by vessels that visit New Zealand more than once, given that annual compliance costs would apply once per unique vessel rather than each time this vessel arrives.

Impact on demand for freight vessel services

New Zealand is highly dependent on maritime transport for international trade. Over 2011, 99% by volume and 77% by value of New Zealand's imports arrived by sea, whilst just short of 100% by volume and 84% by value of New Zealand's exports departed by sea (Statistics New Zealand, 2012a). Any additional intervention that might significantly affect this trade would be of serious concern. We therefore consider whether the compliance costs above could significantly affect demand for the services of freight vessels.

The demand for freight vessel services is often assumed to be nearly perfectly inelastic due to the lack of alternatives available for the vast majority of goods transported by sea. Estimates of the price elasticity of demand range between -0.05 and -0.3 (see, for example, Beenstock and Vergottis, 1993, Meyrick and Associates, 2007, Oum *et al*., 1990). Transportation by sea is the most efficient means of transporting these goods on a tonnekilometre basis and freight costs generally account for only a small proportion of the total costs of these goods. This suggests that all of the additional costs to freight vessels of complying with the proposed IHS could be passed on to customers in higher shipping prices without much fall in demand for shipping services.

Across all five types of freight vessel, the average compliance costs per year, from Table 5 above, are $13,076 per vessel. The volume of freight delivered to New Zealand averages 27,329 tonnes per unique vessel per year (the total volume of imports per year of Figure 1 divided by the annual unique vessel arrivals of Table 2, over 2006 to 2008). This implies that complying with the proposed IHS would add, on average, $0.48 per tonne to shipping costs, including the opportunity costs of the additional time required for improved antifouling treatment of niche areas. Shipping costs can vary considerably according to the types of goods shipped as well as the contract rates negotiated, but the weighted average of shipping costs to New Zealand is currently around $140 per tonne (derived from OECD, 2011, updated to 2012 prices) Complying with the proposed IHS would therefore increase shipping costs per tonne by, on average, 0.34%. If all of this additional cost was passed on to customers in the form of higher shipping prices, a 0.34% increase in price would reduce demand by between 0.02% and 0.10%, under an elasticity of demand of between -0.05 and -0.3 respectively. This equates to a reduction in demand of between 4.7 and 28 tonnes per unique vessel per year for vessels becoming compliant (average additional costs of $13,076 per vessel per year, over 27,329 tonnes per vessel per year are $0.48 per tonne, which represents a 0.34% increase in average shipping costs of $140 per tonne, multiplied by an elasticity of demand of between -0.05 and -0.3 implies a 0.02% to 0.10% decrease in demand, which over 27,329 tonnes per year is 4.7 to 28 tonnes).

If vessels becoming compliant with the proposed IHS spread the additional costs across not only imports but also the exports they carried from New Zealand, the increase in average cost per tonne would be lower, but the demand response would apply over the larger volume of both imports and exports carried. For vessels that also visited Australia and/or California, the increase in average cost per tonne, if spread across the volume carried to and from all jurisdictions with biofouling management standards, would be even lower. It is even possible that, depending on how shipping companies structure their costs, they might spread these compliance costs across all freight carried by these vessels or all vessels in their fleets.

The above application of elasticity of demand suggests that the proposed IHS or voluntary standard would be unlikely to cause much reduction in demand for freight services. Furthermore, around half of all freight vessel arrivals already have sufficiently good biofouling management to be able to comply with the proposed IHS or voluntary standard without incurring any additional costs. Customers most sensitive to price increases may choose shipping services provided by the operators of these vessels.

Cruise vessels

We use a similar approach in modelling compliance costs per vessel for cruise vessels.

Most cruise vessels also already have good biofouling management, including antifouling systems and regular inspections and spot cleaning, to optimise vessel performance. As for freight vessels, we model the additional cost to cruise vessels becoming compliant with the proposed IHS or voluntary standard as that of improving their antifouling treatment of niche areas for biosecurity risks.

Costs of treatment

As for freight vessels, the full cost of applying antifouling coatings to cruise vessels during routine hull maintenance ranges from around $126,000 per vessel weighing up to 5,000 tonnes to over $580,000 per vessel over 200 metres in length, taking five to seven days (NIWA, 2010a, converted to New Zealand dollars and updated to 2012 prices). We weight these costs and time requirements by the approximate size distribution of cruise vessels visiting New Zealand (based on NIWA, 2010a) to derive a weighted average cost and time per vessel. Given the large size of most cruise vessels, the weighted average is close to the upper end of the range.

We again assume that around half the full cost and time per vessel is for treating the hull and half for niche areas, and that vessels becoming compliant with the proposed IHS or voluntary standard would need to increase treatment of niche areas by, on average, around 25%. These assumptions imply average additional treatment costs per vessel becoming compliant of around $69,000, taking an additional 0.9 of a day, on average.

Opportunity costs of time required

Again, we value the opportunity costs of the additional time required for this treatment in terms of the revenue forgone net of operating costs saved, represented by the average daily time charter rate (Kite-Powell and Hoagland, 2002, converted to New Zealand dollars and updated to 2012 prices) plus a 20% margin (as used by PricewaterhouseCoopers, 2011). We again discount this average revenue by 50% to reflect that this additional time in port would be planned, added to when the vessel was already out of service for routine maintenance, so likely to be scheduled for off-peak season or when the opportunity costs were low. This gives average opportunity costs per vessel per day of additional time required of $40,000.

Total costs

With these additional costs being incurred only every five years, the average additional costs for cruise vessels improving antifouling of niche areas to comply with the proposed IHS or voluntary standard would total $20,750 per vessel per year, comprising $13,750 for improved antifouling treatment (around $69,000 spread over five years) and $7,000 in opportunity costs of the time required (around 0.9 of a day at $40,000 per day, spread over five years). In applying these compliance costs per vessel per year, we adjust for multiple arrivals by vessels that visit New Zealand more than once, given that annual compliance costs would be incurred once per unique vessel rather than each time this vessel arrives.

Impact on demand for cruises

Given the importance of the cruise industry to New Zealand's tourism revenue, any additional intervention that might significantly affect the number of visits by cruise vessels would be of serious concern. We therefore consider whether the compliance costs above could significantly affect demand for cruises that call at New Zealand.

The demand for cruises is likely be price elastic because they are considered a luxury good and there are a variety of substitutes available. Environmental Protection Agency (2009) suggests a price elasticity of around -1.4. This suggests that additional costs may be partly passed on to passengers in higher cruise prices and partly absorbed by cruise lines, so that the reduction in demand is less than if all of the additional costs were passed on in prices.

Around 180,000 cruise passengers visit New Zealand each year (NIWA, 2012a). This averages 6,067 passengers per unique vessel per year. The additional costs of complying with the proposed IHS of $20,750 per vessel per year, as modelled above, therefore average $3.42 per passenger, including the opportunity costs of the additional time required for improved antifouling treatment of niche areas. The price of a seven day cruise can be anywhere between around $800 and $4,000 per person. Assuming an average of $1,000, $3.42 equates to 0.34% of this price. If all of the additional cost of complying with the proposed IHS was passed on to passengers in higher cruise prices, a 0.34% increase in price would reduce demand by 0.48%, under an elasticity of demand of -1.4. This equates to a reduction in demand of 29 passengers per unique vessel per year for vessels becoming compliant (additional costs of $20,750 per vessel per year, over 6,067 passengers per year are $3.42 per passenger, which represents a 0.34% increase in a cruise price of $1,000, multiplied by an elasticity of demand of -1.4 implies a 0.48% decrease in demand, which over 6,067 passengers per year is 29 passengers). If only half of the additional cost of complying with the proposed IHS was passed on to passengers in higher cruise prices, a 0.17% increase in price would reduce demand by 0.24%, 15 passengers per unique vessel per year for vessels becoming compliant (half the additional costs of $20,750 per vessel per year, over 6,067 passengers per year are $1.71 per passenger, which represents a 0.17% increase in a cruise price of $1,000, multiplied by an elasticity of demand of -1.4 implies a 0.24% decrease in demand, which over 6,067 passengers per year is 15 passengers).

For vessels that also visit Australia and/or California, the increase in average cost per passenger, if spread across the number of passengers carried to and from all jurisdictions with biofouling management standards, would be even lower. It is even possible that, depending on how cruise lines structure their costs, they might spread these compliance costs across all passengers carried by these vessels or all vessels in their fleets.

The above application of elasticity of demand suggests that the proposed IHS or voluntary standard would be unlikely to cause much reduction in cruise vessel visits to New Zealand. Furthermore, almost half of all cruise vessel arrivals already have sufficiently good biofouling management to be able to comply with the proposed IHS or voluntary standard without incurring any additional costs. Passengers most sensitive to price increases may choose cruises offered by the cruise lines operating these vessels. In addition, due to competition with substitutes, cruise lines are increasingly competing on quality, including by developing specialist cruises for niche markets, which are less price elastic.

Fishing vessels

The fishing vessels of concern for biofouling risks are those arriving in New Zealand from other countries. These typically comprise New Zealand flagged vessels returning from other countries' fishing grounds and foreign flagged vessels arriving in New Zealand on charter to quota owners for use in New Zealand's deep water fisheries (NIWA, 2010b). The proposed IHS would not apply to vessels operating within New Zealand waters only.

For most of these fishing vessels, complying with the proposed IHS or voluntary standard would involve a broader improvement in biofouling management than for freight and cruise vessels. MPI advises that it would assist fishing vessels to achieve compliance by working with the industry to develop a code of practice, which would be based on good hull maintenance and limiting the number of visits to foreign ports. We model the additional cost to fishing vessels becoming compliant with the proposed IHS or voluntary standard as that of improving both the removal of biofouling and application of antifouling coatings during existing routine maintenance, plus additional spot cleaning between applications.

Costs of treatment

The full cost of removing biofouling from fishing vessels during routine hull maintenance ranges from around $2,600 per vessel around 25 metres in length to over $41,000 per vessel weighing over 5,000 tonnes, taking between one and 3.5 days (NIWA, 2010b, updated to 2012 prices). The full cost of applying antifouling coatings to fishing vessels ranges from around $9,300 per vessel around 25 metres in length to over $126,000 per vessel weighing over 5,000 tonnes and takes two to seven days (NIWA, 2010b, updated to 2012 prices). We weight these costs and time requirements by the approximate size distribution of fishing vessels visiting New Zealand (based on NIWA, 2010b) to derive a weighted average cost and time per vessel.

We assume that removal of biofouling and application of antifouling coatings on vessels becoming compliant with the proposed IHS or voluntary standard is currently, on average, around 50% deficient, such that they would additionally incur half the full costs presented above to reduce biofouling to within the allowances. This implies average additional treatment costs per vessel becoming compliant of around $34,000, taking an additional 2.75 days, on average.

Opportunity costs of time required

As for freight and cruise vessels, we value the opportunity costs of the additional time required for this treatment in terms of the revenue forgone net of operating costs saved, represented by the average daily time charter rate (PricewaterhouseCoopers, 2011, converted to New Zealand dollars and updated to 2012 prices) plus a 20% margin (as used by PricewaterhouseCoopers, 2011). We again discount this average revenue by 50% to reflect that this additional time in port would be planned, added to when the vessel was already out of service for routine maintenance, so likely to be scheduled for off-peak season or when the opportunity costs were low. This gives average opportunity costs per vessel per day of additional time required of $8,500. For vessels that already spend significant periods in port (NIWA, 2010b, reports 31% of port visits by fishing vessels to last between 10 and 50 days), there may be no opportunity costs if this additional treatment is scheduled for one of these times.

With these additional costs being incurred only every five years, the average additional cost per vessel per year of improving removal of biofouling and application of antifouling coatings to comply with the proposed IHS or voluntary standard would be as shown in Table 6 below.

Spot cleaning

Accompanying this improvement in antifouling treatment, we model fishing vessels increasing the frequency of spot cleaning by on average one additional clean per year, in each of the four years between the five yearly reapplication antifouling coatings. This would be undertaken in water, so would require development of more effective containment technology than available currently.

Spot cleaning between applications can cost up to $4,500 and take up to half a day for commercial divers to hand clean a large vessel (NIWA, 2010b, converted to New Zealand dollars and updated to 2012 prices). Hand cleaning is suitable for removing sparse or light biofouling. Heavier biofouling may require mechanical cleaning, but, for all but the largest fishing vessels, the current cost and time required for mechanical cleaning (NIWA, 2010b) are greater than those for cleaning out of water, so mechanical cleaning seems unlikely to be used in this context unless lower cost technologies are developed. We assume that, with the improvement in antifouling treatment and for spot cleaning additional to that already undertaken, hand cleaning would generally be sufficient.

Assuming that a small or medium sized vessel costs half as much, and takes half as long, to clean, we weight these spot cleaning costs and time requirements by the approximate size distribution of fishing vessels visiting New Zealand (based on NIWA, 2010b) to derive a weighted average cost and time per vessel of around $3,500 and half a day. For consistency with other vessel types, we include the opportunity costs of the additional time required for spot cleaning, although given that this would comprise only a few hours, it could probably be accommodated within existing port visits. We value these opportunity costs at the same rate as used above, $8,500 per vessel per day of additional time required.

Total costs

This additional spot cleaning would take the total average additional costs of improving biofouling management to comply with the proposed IHS or voluntary standard to $17,675 per vessel per year (around $34,000 for improved biofouling removal and antifouling application, taking around 2.75 days at $8,500 per day in opportunity costs, spread over five years; plus around $3,500 for additional spot cleaning, taking around half a day at $8,500 per day in opportunity costs, in four out of five years).

Table 6 Average additional cost per vessel per year of improved biofouling management – fishing vessels
$, in 2012 prices

Treatment	Costs of treatment	Opportunity costs of time required	Total costs
Biofouling removal and antifouling application	6,800	4,675	11,475
Spot cleaning	2,800	3,400	6,200
Total	9,600	8,075	17,675

In applying these compliance costs per vessel per year, we adjust for multiple arrivals by vessels that visit New Zealand more than once, given that annual compliance costs would be incurred once per unique vessel rather than each time this vessel arrives.

Recreational vessels

MPI already targets international yachts in encouraging vessel cleaning and antifouling.

Recreational vessels can manage biofouling by applying antifouling coatings before the start of each cruise and regularly inspecting and maintaining coatings throughout the cruise. Antifouling may no longer be very effective, however, by the time vessels reach New Zealand in what can be a one to two year cruise. To arrive "clean", hulls would also need cleaning before the last leg of the journey to New Zealand. This could be done by crew at negligible additional cost. We therefore do not model any additional costs for recreational vessels becoming compliant with the proposed IHS or voluntary standard.

Slow moving/specialist vessels

MPI is already working with the oil industry on ways to allow exploration rigs to enter New Zealand for operations off the coast without carrying non-indigenous species in their biofouling.

Slow moving/specialist vessels were not included in MPI's biofouling survey and MPI did not model compliance rates for this vessel type, nor its contribution to reducing non-indigenous species introduction rates. We therefore do not include the costs, nor benefits, for this vessel type in assessing the costs and benefits of the proposed IHS.

This vessel type could, however, face the highest compliance costs per vessel. As journeys to New Zealand are infrequent, slow moving/specialist vessels would be likely to become compliant by dry docking and cleaning before departure for New Zealand or immediately on arrival. The cost of dry docking and cleaning can range from around $77,000 for a barge to around $250,000 for a mobile offshore drilling rig, taking two to 4.5 days at average opportunity costs per day of around $5,500 to $138,000 (PricewaterhouseCoopers, 2011, converted to New Zealand dollars and updated to 2012 prices). Weighted by the possible distribution of slow moving/specialist vessels (based on PricewaterhouseCoopers, 2011) suggests a total average additional cost per vessel per visit of $180,000.

Given this cost, it may be worthwhile for vessels that expect to visit New Zealand more than once within five years, or to visit both New Zealand and Australia or California, to consider adopting the same form of compliance as freight and cruise vessels in applying antifouling coatings when dry docked for routine maintenance, maintained by regular inspections and spot cleaning, instead of dry docking and cleaning especially for each visit.

Summary of compliance costs per vessel

Table 7 summarises the ongoing average additional costs per vessel per year, by vessel type, to vessels improving their biofouling management to comply with the proposed IHS or voluntary standard. These costs reflect:

- freight and cruise vessels – improved antifouling treatment of niche areas, every five years during existing routine maintenance
- fishing vessels – improved removal of biofouling and application of antifouling coatings, every five years during existing routine maintenance, plus additional spot cleaning between applications and
- recreational vessels – cleaning of hulls by crew before arrival in New Zealand.

Compliance costs are highest for cruise vessels and lowest for recreational vessels. We consider the effect of lower or higher compliance costs per vessel in the sensitivity analysis of Section 3.4 below. Experience of the proposed IHS over its initial four year voluntary period may provide more accurate information on the likely costs to vessel owners and operators.

Table 7 Average compliance costs per vessel per year
$, in 2012 prices

Vessel type	Costs of treatment	Opportunity costs of time required	Total costs
Container	11,250	2,275	13,525
Bulk	10,013	825	10,838
General cargo	8,750	1,800	10,550
Tanker	12,500	2,031	14,531
Other commercial	13,750	2,188	15,938
Cruise	13,750	7,000	20,750
Fishing	9,600	8,075	17,675
Recreational	0	0	0

2.6.4 Action costs

Action rates

Of vessels that did not comply with the proposed IHS or the baseline scenario's voluntary standard, a proportion would be given warnings and a proportion directed to take action to mitigate their biofouling risks.

The rates of non-compliance, by vessel type, are determined by the compliance rates adopted in the CBA, shown in Section 2.6.3 above (i.e. non-compliant vessel arrivals equal total vessel arrivals minus compliant vessel arrivals).

We do not model any additional costs from warnings directly. Indirectly, warnings could be expected to contribute to the compliance costs modelled in Section 2.6.3 above, to the extent that they encouraged vessels to improve their biofouling management to become compliant with the proposed IHS or voluntary standard for subsequent visits.

For the purpose of this CBA, MPI has also modelled the proportion of non-compliant vessel arrivals that it might direct to take action to mitigate their biofouling risks under the proposed IHS and the voluntary standard. The action rates adopted in the CBA must be consistent with the compliance rates adopted, given that the two rates are interrelated. A higher action rate could be expected to encourage a higher compliance rate. A higher compliance rate would reduce the non-compliance rate and therefore the proportion of vessel arrivals to which the action rate would apply, which might also influence the action rate set by MPI. The relationship between compliance rates and action rates would also differ by vessel type. Some vessel types, such as cruise vessels, may be able to become compliant relatively easily and therefore not need as high action rates to encourage the same rate of compliance as vessel types that might find it more difficult or be more resistant to becoming compliant.

In modelling compliance rates, MPI used data from the biofouling survey on vessels with biofouling above what would be the allowances of the proposed IHS or the voluntary standard to derive the distribution of vessels according to amount of biofouling, for each vessel type. MPI also used this distribution in modelling action rates, given that directing vessels to take action would be based on biofouling risks.

These action rates are shown in Table 8. Under the voluntary standard and during the voluntary period of the proposed IHS, only recreational vessels would be directed to take action to mitigate their biofouling risks. Action rates would be the same under each of the two international scenarios (voluntary or mandatory standards in Australia and California). MPI was unable to model compliance rates and therefore action rates for slow moving/specialist vessels, as the biofouling survey did not include this vessel type. We consider the effect of lower or higher action rates in the sensitivity analysis of Section 3.4 below. Experience of the proposed IHS over its initial four year voluntary period may provide more accurate information on the likely responses of vessel owners and operators.

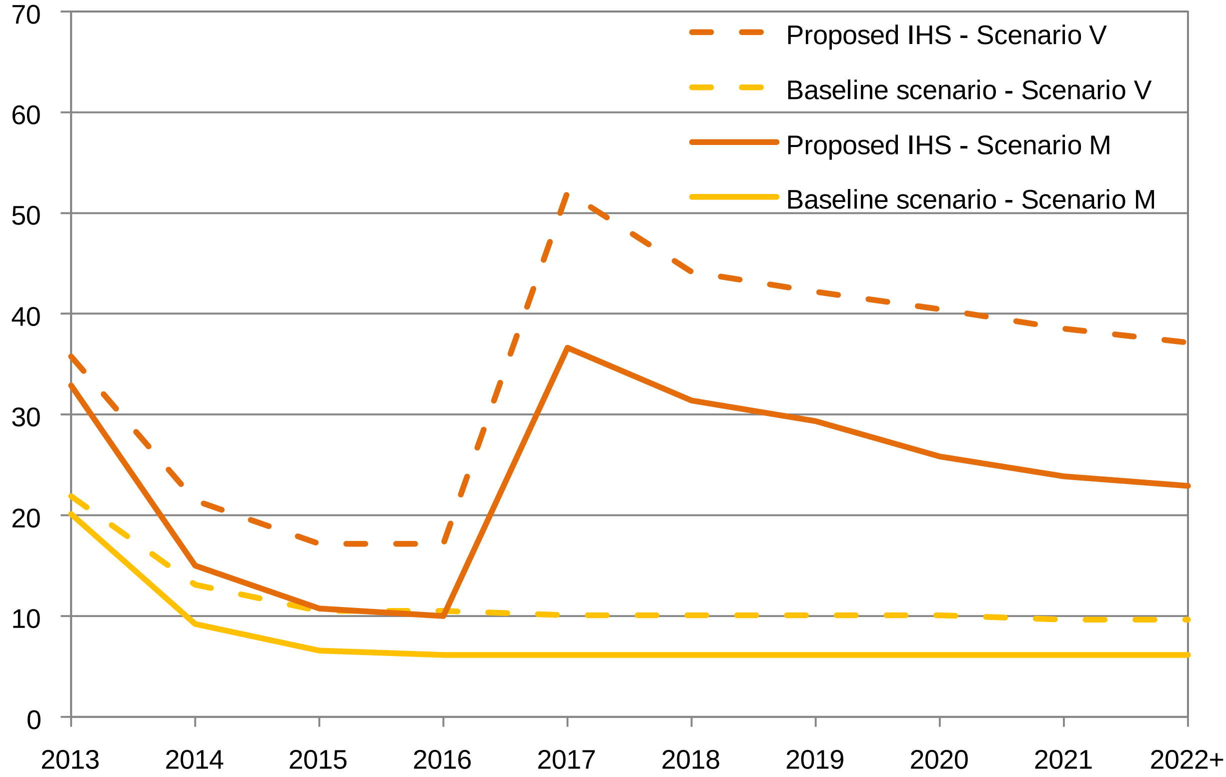
Table 8 Action rates

Percentage of non-compliant vessels directed to take action to mitigate biofouling risk, same under each international scenario

Year	0	1	2	3	4	5	6	7	8	9	10+
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022+
Baseline scenario (voluntary standard)											
Container		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Bulk		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
General cargo		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tanker		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other commercial		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cruise		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fishing		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Recreational		7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%
Slow moving/specialist											
Proposed IHS											
Container		0%	0%	0%	0%	2.6%	2.6%	2.6%	2.6%	2.6%	2.6%
Bulk		0%	0%	0%	0%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%
General cargo		0%	0%	0%	0%	3.9%	3.9%	3.9%	3.9%	3.9%	3.9%
Tanker		0%	0%	0%	0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
Other commercial		0%	0%	0%	0%	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%
Cruise		0%	0%	0%	0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
Fishing		0%	0%	0%	0%	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%
Recreational		11.4%	11.4%	11.4%	11.4%	22.9%	22.9%	22.9%	22.9%	22.9%	22.9%
Slow moving/specialist											

Applying non-compliance rates and these action rates to the average annual vessel arrival numbers of Table 1 gives the total number of vessel arrivals directed to take action shown in Figure 3.

Figure 3 Number of vessel arrivals directed to take action per year
Year to December



As shown in Figure 3, the number of vessel arrivals directed to take action would increase in year 5 (2017) when the proposed IHS became mandatory, but otherwise decline over time as compliance rates increased. The compliance rates and action rates adopted suggest that, at most, around 52 vessel arrivals per year would be directed to take action under the proposed IHS, dropping to an annual average of around 37 (Scenario V) or 23 (Scenario M) vessel arrivals from year 10 (2022) onwards. Of this annual average, generally over half would be recreational vessel arrivals and over a third freight vessel arrivals, with fishing and cruise vessel arrivals together comprising only around 2% to 3%.

The number of vessel arrivals directed to take action would be lower if Australia and California had mandatory standards (Scenario M) than if their standards were voluntary (Scenario V), due to higher compliance rates to the extent that vessels arriving in New Zealand also visited these jurisdictions and already complied with their standards. Under both of these international scenarios, more vessels would be directed to take action under the proposed IHS than under the baseline scenario's voluntary standard. Under the voluntary standard, only severely fouled recreational vessels would be directed to take action. In assessing the costs of the proposed IHS relative to the baseline scenario, however, we are interested in the *difference* in number of vessels directed to take action – how much *additional* action would be directed under the proposed IHS than the voluntary standard. As can be seen in Figure 3, the proposed IHS would result in a smaller addition to action directed if Australia and California had mandatory standards and make a greater difference if their standards were only voluntary.

Table 9 shows the additional action directed under the proposed IHS (the difference between the proposed IHS and the voluntary standard).

Table 9 Additional action directed under proposed IHS
Difference in percentage of non-compliant vessel arrivals directed to take action to mitigate biofouling risk, same under each international scenario

Year	**0 2012**	**1 2013**	**2 2014**	**3 2015**	**4 2016**	**5 2017**	**6 2018**	**7 2019**	**8 2020**	**9 2021**	**10+ 2022+**
Container		0%	0%	0%	0%	2.6%	2.6%	2.6%	2.6%	2.6%	2.6%
Bulk		0%	0%	0%	0%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%
General cargo		0%	0%	0%	0%	3.9%	3.9%	3.9%	3.9%	3.9%	3.9%
Tanker		0%	0%	0%	0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
Other commercial		0%	0%	0%	0%	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%
Cruise		0%	0%	0%	0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
Fishing		0%	0%	0%	0%	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%
Recreational		4.4%	4.4%	4.4%	4.4%	15.9%	15.9%	15.9%	15.9%	15.9%	15.9%
Slow moving/specialist											

Source: Modelled by MPI, August 2012

Action costs per vessel

Freight vessels

The type of action vessels would be directed to take to mitigate their biofouling risks would differ by vessel type. MPI advises that it would direct freight vessels to leave New Zealand. In effect, vessels would be allowed to unload and load at the port of first arrival only, provided that they leave within 24 hours or as soon as practicable.

Costs of action

For vessels already planning to call at only one New Zealand port for less than one day, being directed to leave within 24 hours would incur no additional costs. Currently, on average 31% of container vessel arrivals, 4% of bulk vessel arrivals, 15% of general cargo vessel arrivals, 26% of tanker arrivals and 27% of other cargo vessel arrivals visit a single port for less than one day (calculated by MPI from New Zealand Customs Service data, December 2012). Applied to the vessel arrival numbers of Table 1, these amount to almost 24% of all freight vessel arrivals. Indeed, because being directed to take action would not incur any additional costs for these vessels, non-compliance could be expected to be more common in this subgroup, except to the extent that these vessels also visited Australia and/or California and already complied with these jurisdictions' standards. We make the modest assumption that these single port rapid turnaround vessels would be twice as likely to be amongst the vessels directed to leave (i.e. 47% of all freight vessel arrivals directed to leave, ranging from 8% of bulk vessel arrival to 62% of container vessel arrivals).

For vessels scheduled to call at multiple ports around New Zealand or at a single port for more than one day, being directed to leave New Zealand within 24 hours would cause significant disruption to their ability to deliver and pick up freight. The costs would depend very much on each vessel's itinerary and load schedule, but, as an illustrative example, consider a vessel scheduled to call at the ports of Lyttelton, then Auckland, on its way to Australia. If this vessel was directed to leave New Zealand, it would be able to unload and load at Lyttelton only. It would have been carrying some freight for delivery to Lyttelton, some for Auckland and some for Australia and possibly subsequent countries on its route. To fill the space vacated by delivery, it may also have been planning to pick up freight at Lyttelton and Auckland and some of the freight picked up at Lyttelton may have been for delivery to Auckland. It would now have to unload all New Zealand bound freight at Lytlleton. It would be unable to deliver any freight to Auckland, to pick up freight at Lyttelton for delivery to Auckland and to pick up any freight at Auckland. It would need to make alternative arrangements for delivering and picking up this freight and would also want to take on additional freight at Lyttelton, to the extent possible within its allowed 24 hours, to fill the vacated space to Australia. In so doing, it may be able to reconfigure load schedules across other vessels in its fleet, depending on which ports these vessels were scheduled to visit, how soon and how much space they would have available, to minimise costs (Notteboom, 2006).

Replicating the constrained optimisation models that shipping companies use for load scheduling across their fleets is beyond the scope of this CBA. For the purpose of this CBA, we model a simple indicative example of average additional costs from being directed to leave New Zealand in terms of the costs of forwarding freight to other ports in New Zealand plus penalties for late delivery of this freight.

The volume of freight delivered to New Zealand averages 7,500 tonnes per vessel arrival (the total volume of imports per year of Figure 1 divided by the annual vessel arrivals of Table 1, over 2006 to 2008). We model an average of 50% of this freight having to be forwarded to other ports elsewhere in New Zealand when a vessel was directed to leave New Zealand after unloading at the port of first arrival only. Pacific Logistics (2011) estimates the cost of forwarding freight between Auckland and Christchurch at around $144 per tonne if coastal shipping is used, compared with $196 per tonne by rail or $440 per tonne by road (updated to 2012 prices). On this route, not only is road transport not a costeffective option, but Pacific Logistics (2011) notes that no road transport companies it contacted were willing to provide a quote for transport from Auckland to Christchurch because there is generally little or no back load for the return journey. The estimates of Pacific Logistics (2011) are based on forwarding the contents of a container (specifically, electrical goods and componentry). Shipping costs can vary considerably according to the types of goods shipped as well as the contract rates negotiated, but weighted average shipping costs to New Zealand suggest shipping by bulk vessel costs around a quarter and by tanker around a sixth of the cost of shipping by container vessel (based on OECD, 2011; note that this includes general cargo and other commercial vessels in its container vessel category). We assume the same ratios of bulk and tanker shipping costs to container shipping costs for coastal shipping, provided that suitable vessels and transfer facilities are available. Weighted by the relative volumes of freight delivered to New Zealand by container, bulk and tanker vessels (OECD, 2011), these indicate an average cost for forwarding freight by coastal shipping of $69 per tonne.

For forwarding 50% of the 7,500 tonnes of freight delivered to New Zealand per vessel arrival, this implies an average freight forwarding cost per vessel directed to leave New Zealand of around $260,000, if by coastal shipping (50% of 7,500 tonnes at $69 per tonne). This would cost almost three times as much by rail or over six times as much by road. The cost of forwarding freight to another international port, such as the freight that the vessel in the above example was scheduled to collect from Auckland for delivery to Australia or subsequent countries on its route, would be greater, but we assume, for simplicity, that this would be offset by revenue from additional freight taken on at Lyttelton.

Costs of delays

Even with coastal shipping able to forward freight to its intended port elsewhere in New Zealand, the additional time taken to secure this alternative transport, to await available capacity, to unload freight from the international vessel and to load it onto coastal vessel(s) would be likely to cause some delay to delivery. For New Zealand, Nathan Associates (2007) estimates the cost to consumers of delays at the border to be equivalent to 1% of the value of the imports delayed per day of delay. The value of freight delivered to New Zealand averages over $15 million per vessel arrival (the total value of imports per year of Figure 1, updated to 2012 prices, divided by the annual freight vessel arrivals of Table 1, over 2006 to 2008), although varies widely by type of freight. Assuming that contract penalties for late delivery reflect the cost to consumers of delay, we adopt $75,000 as the average penalty per vessel per day for late delivery (1% of the 50% of $15 million worth of freight delayed). We assume an average delay of two days, incurring $150,000 in contract penalties per vessel.

Customers who considered these contract penalties insufficient compensation for the costs to them of late delivery may also take legal action, although some may have insurance against late delivery if critical to their business (e.g. if late delivery of inputs would hold up high value production). Given the importance of reliability in this industry, delays may also cause loss of future business from damage to reputation.

Total costs

The total average costs per vessel directed to leave New Zealand are therefore modelled as $410,000, in freight forwarding costs and late delivery penalties, except for vessels that were already scheduled to visit only one New Zealand port for less than one day.

A vessel directed to leave may also incur additional port charges for additional unloading and loading at the port of first arrival, but might achieve some saving in fuel costs from not calling at other New Zealand ports and avoid additional port charges from arriving early at the next ports by travelling at a slower speed to the next country on its route.

The above action costs do not allow for any adaptation over time, other than by vessels becoming compliant. Over the longer run, vessels remaining non-compliant could respond to the proposed IHS or voluntary standard by adjusting their schedules to reduce their exposure to costs, especially the risk of being unable to deliver and pick up loads. One possible adaptation might be to reduce the number of ports visited to one and length of stay planned in this port to one day, to avoid any disruption if directed to leave. Another might be to drop New Zealand from scheduled routes. This could accelerate the recent trend, for some goods, for New Zealand bound freight to be offloaded in Australia for on-shipping to New Zealand.

Impact on demand for freight vessel services

In Section 2.6.3 above, we considered whether the additional costs of complying with the proposed IHS could significantly affect demand for the services of freight vessels. Although only a small percentage of non-compliant vessels would be directed to leave New Zealand, for these vessels these action costs could have a greater impact.

Action costs of $410,000 per vessel, over the average volume of freight delivered to New Zealand of 7,500 tonnes per vessel arrival, would add, on average, $54.67 per tonne, 39%, to their shipping costs. If all of these additional costs were passed on to customers in the form of higher shipping prices, a 39% increase in price would reduce demand by between 2.0% and 11.7%, under an elasticity of demand of between -0.05 and -0.3 respectively. This equates to a reduction in demand of between 146 and 878 tonnes per vessel directed to leave New Zealand (average additional costs of $410,000 per vessel, over 7,500 tonnes per vessel are $54.67 per tonne, which represents a 39% increase in average shipping costs of $140 per tonne, multiplied by an elasticity of demand of between -0.05 and -0.3 implies a 2.0% to 11.7% decrease in demand, which over 7,500 tonnes is 146 to 878 tonnes).

If vessels directed to leave New Zealand spread the additional costs across not only the imports delivered on this arrival but all imports they delivered to New Zealand and/or also the exports they carried from New Zealand, the increase in average cost per tonne would be lower, but the demand response would apply over the larger volume of imports and exports carried. Depending on how shipping companies structure their costs, they might even spread these action costs across all freight carried by these vessels or all vessels in their fleets.

For individual vessels, demand is likely to be more elastic if there are other vessels available that do not face the additional costs, which customers could choose. High action costs to non-compliant vessels would not translate into a reduction in demand across the industry, given that there would be a much larger number of compliant vessels (as well as noncompliant vessels not directed to leave), which customers could choose. Furthermore, for non-compliant vessels directed to leave, the loss of business from damage to reputation for reliable delivery would be likely to be much greater than any price response.

Cruise vessels

MPI advises that it would direct small “eco-cruisers” (vessels providing eco-tourism based cruises) to spot clean. These are generally cruise vessels less than 125 metres long, which comprise only around 9% of cruise vessel arrivals to New Zealand (NIWA, 2011). Larger cruise vessels would be given warnings only.

This action assumes development of effective containment technology for cleaning in water, as well as establishment of approved cleaning contractors.

Costs of action

Hand cleaning a large vessel of sparse to light biofouling can cost up to $4,500 and take up to half a day. Mechanical cleaning of light to moderate biofouling can cost from around $18,300 for a 50 metre vessel to around $29,500 for a 200 metre vessel and take one to 2.5 days (NIWA, 2011, converted to New Zealand dollars and updated to 2012 prices). Given that most cruise vessels are already regularly spot cleaned to maintain vessel performance, we assume that hand cleaning would suffice for 75% of vessels directed to spot clean and 25% of vessels would require mechanical cleaning. For vessels up to 125 metres long, the above assumptions imply average additional costs per vessel directed to spot clean of around $7,500, taking an average of 0.75 of a day.

Costs of delays

Following Kite-Powell and Hoagland (2002), we value the opportunity costs of an unplanned in-port delay in terms of average revenue per day net of operating costs saved whilst in port, represented by the average daily time charter rate (Kite-Powell and Hoagland, 2002, converted to New Zealand dollars and updated to 2012 prices) plus a 20% margin (as used by PricewaterhouseCoopers, 2011). Across cruise vessels of all sizes, this gives average opportunity costs per vessel per day of delay of $80,000. For vessels up to 125 metres long, we adopt half this rate, $40,000 per day, on the basis that although these vessels are smaller than the average and carry far fewer passengers, many provide higher price specialist cruises to niche markets.

The length of delay caused by being directed to spot clean would depend on how soon spot cleaning could commence following arrival and how long it would take to complete beyond the scheduled departure time. Currently, 73% of port visits by cruise vessels last no more than 24 hours and passengers have an average of 10 to 12 hours ashore at each port (NIWA, 2011). If it could commence immediately on arrival, hand cleaning could be completed within this planned time in port and therefore cause no delay. Mechanical cleaning of vessels up to 125 metres long would take up to 1.5 days, so even if it could commence immediately, would still cause a delay of around half a day beyond the average time vessels planned to stay in port. With the assumption that 75% of vessels would be hand cleaned and 25% require mechanical cleaning, these delays imply an average delay per vessel across all vessels directed to spot clean of around one eighth of a day, incurring opportunity costs of $5,000.

Delays could be longer if spot cleaning had to await granting of resource consents and availability of cleaning contractors. Resource consent delays might be avoided by obtaining general permits from regional authorities, which allowed a number of vessels to be cleaned per year for biosecurity purposes, as and when required, or an exemption under the Biosecurity Act 1993 (NIWA, 2011). Given the importance of the cruise industry to New Zealand's tourism revenue, it seems likely that if directing cruise vessels to spot clean became a regular occurrence, for major ports at least, general permits or exemptions would be sought in advance and approved cleaning contractors be established and available at short notice to minimise delays.

Cruise vessels would also face other, potentially much larger, costs from delays. These include additional port charges for staying at the port of first arrival longer than scheduled, whilst spot cleaning was completed, and penalties for arriving later than scheduled at the next port. Penalties can be up to $100,000 for missing a scheduled port arrival time by up to three hours (NIWA, 2011). Delays can also cause major disruption to passengers, for not only excursions but also travel connections and accommodation in ports where passengers join or leave the cruise. Cruise lines typically compensate passengers for the costs of such disruptions, but may still suffer loss of future revenue from damage to reputation. The costs of arriving late at the next port might be reduced by adopting a faster speed, once underway, to make up time, but at the expense of higher fuel costs.

For vessels up to 125 metres long, port penalties and passenger compensation for delays may be somewhat lower, given that these vessels are smaller than average and carry far fewer passengers. If, in addition to the above opportunity cost, the delay for spot cleaning a vessel up to 125 metres long incurred even just one $50,000 port penalty per day of delay and the equivalent in compensation paid to passengers, the total costs of delays would average $17,500 per vessel directed to spot clean (completed without delay for the 75% of vessels hand cleaned and causing a delay averaging half a day for the 25% of vessels mechanically cleaned, at $40,000 opportunity costs per day and $100,000 in penalties and compensation per day).

Cruise passengers are an important source of tourism revenue, estimated to spend on average $110 each per day whilst in New Zealand (Market Economics, 2008). Because the additional delay for spot cleaning would be spent in port, we do not include as a cost to the New Zealand economy any significant loss in spending by cruise passengers. There could, however, be some diversion of spending between regional economies. For example, after more time ashore than planned, resulting in more spending, at the port of first arrival, passengers may be allowed less time, resulting in less spending, at the next port as the vessel seeks to make up time.

Total costs

Being directed to spot clean would therefore incur total additional costs of $25,000 per vessel, on average, of which only 30% ($7,500) would be cleaning costs and the rest costs resulting from delays.

These action costs do not allow for any adaptation over time, other than by vessels becoming compliant. Over the longer run, vessels remaining non-compliant could respond to the proposed IHS or voluntary standard by adjusting their cruise schedules to reduce their exposure to costs, especially the risk of delays. One possible adaptation might be to increase the length of visit planned for the port of first arrival to long enough to accommodate time for spot cleaning, if directed to do so, without causing delays.

Impact on demand for cruises

In Section 2.6.3 above, we considered whether the additional costs of complying with the proposed IHS could significantly affect demand for cruises that call at New Zealand. Although only a small percentage of non-compliant vessels would be directed to spot clean, for these vessels these action costs could have a greater impact.

If the average number of passengers on cruise vessels up to 125 metres long is 100 (based on NIWA, 2012a), action costs of $25,000 per vessel including the costs of delays, as modelled above, would average $250 per passenger. The price of a cruise on one of these vessels is likely to be higher than the average across all cruise vessels and the price elasticity of demand somewhat lower, given that many of these smaller vessels provide specialist cruises to niche markets. If the average cruise price is $3,000, action costs of $250 per passenger represent 8.3% of the cruise price. If all of these additional costs were passed on to passengers in the form of a higher cruise price and the elasticity of demand was slightly lower, say, -1.2, a 8.3% increase in price would reduce demand by 10.0%. This equates to a reduction in demand of 10 passengers per vessel directed to spot clean (additional costs of $25,000 per vessel, over 100 passengers are $250 per passenger, which represents a 8.3% increase in cruise price, multiplied by an elasticity of demand of -1.2 implies a 10.0% decrease in demand, which over 100 passengers is 10 passengers). If only half of the additional costs were passed on to passengers in higher cruise prices, a 4.2% increase in price would reduce demand by 5.0%, five passengers per vessel directed to spot clean (half the additional costs of $25,000 per vessel, over 100 passengers are $125 per passenger, which represents a 4.2% increase in cruise price, multiplied by an elasticity of demand of -1.2 implies a 5.0% decrease in demand, which over 100 passengers is five passengers).

If vessels directed to spot clean spread these additional costs across not only the passengers carried on this arrival but all passengers they carried to and/or from New Zealand, the increase in average cost per passenger would be lower, but the demand response would apply over the larger number of passengers carried. Depending on how cruise lines structure their costs, they might even spread these action costs across all passengers carried by these vessels or all vessels in their fleets.

For individual vessels, demand is likely to be more elastic if there are other vessels available that do not face the additional costs, which passengers could choose. Action costs to noncompliant vessels would not translate into a reduction in demand across the industry, given that there would be a much larger number of compliant vessels (as well as non-compliant vessels not directed to spot clean), which customers could choose. Furthermore, for noncompliant vessels directed to spot clean, the reduction in demand from damage to reputation due to delays would be likely to be at least as great as any price response.

Fishing vessels

MPI advises that although it may direct some fishing vessels to be spot cleaned and some to leave New Zealand, in most cases it would direct fishing vessels to be hauled out or dry docked and cleaned.

Costs of action

Out-of-water removal of biofouling from fishing vessels costs from around $4,000 for a 25 metre vessel, including the costs of removal from and return to the water, to around $40,000 for a 5,000 tonne vessel, including the cost of dry dock hire, and takes between one and 3.5 days (NIWA, 2010b, updated to 2012 prices). We weight these costs and time requirements by the approximate size distribution of fishing vessels arriving in New Zealand (based on NIWA, 2010b) to derive a weighted average cost and time per vessel of $17,000 and two days, respectively.

Costs of delays

We again value the opportunity costs of an unplanned in-port delay in terms of average revenue per day net of operating costs saved whilst in port, represented by the average daily time charter rate plus a 20% margin (PricewaterhouseCoopers, 2011, converted to New Zealand dollars and updated to 2012 prices). This gives an average opportunity cost per vessel per day of delay of also $17,000. The opportunity costs may be lower or even nil for vessels that were already planning to spend some or all of this time in port, but because this delay would be unplanned, it could just as easily occur when vessels were planning to return to sea immediately after unloading, provisioning and refuelling to recommence fishing.

Total costs

Being directed to haul out or dry dock and clean would therefore incur total average additional costs per vessel of $51,000 ($17,000 in cleaning costs, taking two days at $17,000 per day in opportunity costs).

Recreational vessels

MPI advises that it would direct recreational vessels to be hauled out and cleaned.

Hauling a vessel out of the water and cleaning its hull of biofouling can cost from $219 for a yacht shorter than 10 metres to $4,500 for a yacht longer than 35 metres and can be completed in a few hours (NIWA, 2010c and MPI). We weight the cost by the size distribution of recreational vessels visiting New Zealand (NIWA, 2010c). This distribution is highly skewed towards the lower end of the range, with over two thirds of arriving vessels between 10 and 16 metres long. We adopt the weighted average cost (mean) of $750 per vessel, but, given the skewed size distribution, the mid-point (median) and most common (mode) cost are much lower at around $420 per vessel.

Between half and three-quarters of visiting recreational vessels already have maintenance and repairs undertaken whilst in New Zealand (NIWA, 2010c), although in most cases at the end of the cruise. Given publicity of New Zealand's biofouling management requirements and the ease with which vessels could avoid action costs by in-water cleaning by crew before arrival to comply with the proposed IHS or voluntary standard, it is therefore likely that a significant proportion of the vessels directed to be hauled out and cleaned would be noncompliant specifically because they were already planning to undertake routine maintenance on or shortly after arrival in New Zealand and would therefore face no additional action costs (although some may have to bring this forward slightly to immediately on arrival). We assume that these comprise 20% of vessels directed to be hauled out and cleaned.

Recreational vessels spend an average of 258 days in New Zealand (NIWA, 2010c), over which they spend around $20,000 to $30,000 (Williamson, 2008). It therefore seems unlikely that the additional cost and time to haul out and clean on arrival, if so directed, would be a significant deterrent to visiting New Zealand, especially given that this could easily be avoided by in-water cleaning by crew to arrive "clean".

It therefore also seems unlikely that the proposed IHS or voluntary standard would cause a reduction in demand for New Zealand boatyard services. In-water cleaning by crew before arrival to comply with the proposed IHS or voluntary standard would not be a substitute for boatyard services. Boatyards would face additional demand from non-compliant vessels directed to be hauled out and cleaned, beyond those already planning to undertake maintenance and repairs during their time in New Zealand. It is possible that some of these additional vessels might also take this opportunity to undertake repairs that they would otherwise have left until after leaving New Zealand.

Slow moving/specialist vessels

MPI expects that all slow moving/specialist vessels would pre-arrange how they would comply with the proposed IHS or voluntary standard and therefore none need to be directed to take action to mitigate their biofouling risks.

Summary of action costs per vessel

Table 10 summarises the average additional costs per vessel, by vessel type, to noncompliant vessels directed to take action to mitigate their biofouling risks. These costs reflect:

- freight vessels – directed to leave New Zealand within 24 hours or as soon as practicable, after unloading and loading at port of first arrival only
- cruise vessels less than 125 metres long – directed to spot clean
- fishing vessels – directed to haul out or dry dock and clean and
- recreational vessels – directed to haul out and clean.

Action costs are highest for freight vessels and lowest for recreational vessels. We consider the effect of lower or higher action costs per vessel in the sensitivity analysis of Section 3.4 below. Experience of the proposed IHS over its initial four year voluntary period may provide more accurate information on the likely costs to vessel owners and operators.

Table 10 Average action costs per vessel
$, in 2012 prices

Vessel type	Costs of action	Costs of delays	Total costs
Container[1]	260,000	150,000	410,000
Bulk[1]	260,000	150,000	410,000
General cargo[1]	260,000	150,000	410,000
Tanker[1]	260,000	150,000	410,000
Other commercial[1]	260,000	150,000	410,000
Cruise[2]	7,500	17,500	25,000
Fishing	17,000	34,000	51,000
Recreational[3]	750	0	750

Notes: [1] 0 for vessels already planning to call at only one New Zealand port for less than one day, [2] 0 for vessels over 125 metres long, [3] 0 for vessels already planning to haul out and clean on or shortly after arrival

2.6.5 Summary of costs

Table 11 summarises the two types of costs modelled in this CBA – ongoing annual compliance costs to vessels improving their biofouling management to comply with the proposed IHS or voluntary standard and one-off action costs to non-compliant vessels directed to take action to mitigate their biofouling risks. These costs include opportunity costs of time required and costs of delays.

Table 11 Summary of costs per vessel
$, in 2012 prices

Vessel type	Compliance costs	Action costs
Container	13,525	410,000
Bulk	10,838	410,000
General cargo	10,550	410,000
Tanker	14,531	410,000
Other commercial	15,938	410,000
Cruise	20,750	25,000
Fishing	17,675	51,000
Recreational	0	750

For all types of vessels, these costs suggest that, on average, it would be less costly to become compliant with the proposed IHS than to remain non-compliant if directed to take action to mitigate biofouling risks.

2.7 Benefits

The objective of both the proposed IHS and the voluntary standard would be, through improving vessel biofouling management, to reduce the rate of introduction of new nonindigenous marine species to New Zealand.

There are two main components in modelling the benefits of the proposed IHS relative to the baseline scenario of a voluntary standard:

- the reduction in number of new non-indigenous species introduced and
- the avoided impacts of these species on New Zealand's economy, environment and/or health and well-being of its people.

We assess the potential impacts avoided on:

- initial incursion response,
- aquaculture,
- commercial fishing,
- coastal infrastructure,
- marine tourism and recreation,
- recreational fishing,
- recreational shellfish gathering,
- recreational use of beaches,
- human health and
- indigenous biodiversity.

We also assess the potential incidental benefits of improved biofouling management on vessel fuel efficiency.

2.7.1 Rates of introduction of non-indigenous species

MPI estimates the current rate of introduction of non-indigenous marine species not previously known to be in New Zealand to average 3.78 species per year, based on a total of 34 new species recorded over the nine year period 2000 to 2008 inclusive.

In modelling the vessel compliance rates of Section 2.6.3 and non-compliant vessel action rates of Section 2.6.4 above, MPI has also modelled what their combined effect might be in reducing the rates of introduction of non-indigenous species. This modelling was again informed by the amount and type of biofouling found on each type of vessel in the recent survey of international vessels arriving in New Zealand (Ministry of Agriculture and Forestry, 2010). These rates of introduction are shown in Table 12 below under the proposed IHS and the baseline scenario's voluntary standard for each of the international scenarios modelled (voluntary or mandatory standards in Australia and California). With compliance rates assumed to reach their upper limits in year 10 (2022) and to remain constant thereafter, MPI assumes no further reduction in average non-indigenous species introduction rates from year 10.

These introduction rates pertain to all species not previously known to be in New Zealand. Some of these species may have little or no impact. For the purpose of this CBA, however, our analysis of the benefits of the proposed IHS or voluntary standard is limited to new species that pose a major biosecurity risk. Given that, in Sections 2.7.2 to 2.7.12 below, we model the avoided impacts of a sample of species of major biosecurity risk, we must use the reduction in rates of introduction of these species. Applying the reduction in rates of introduction of all new species to the avoided impacts of new species that pose a major biosecurity risk would overstate the benefits of both the proposed IHS and the voluntary standard.

As an indicator of the proportion of all species introduced that might be species of major biosecurity risk, we consider how many marine species introductions have prompted spending on major initial incursion responses, since introduction of the ballast water IHS in 2005 reduced the risk of entry via this pathway. MPI data show expenditure on seven major marine initial incursion responses over the six years 2005/06 to 2010/11 inclusive (Section 2.7.2 below provides further details of these incursion responses). Although the timeframe is not the same, the average number of major marine initial incursion responses per year suggests that, of the estimated current average rate of introduction of non-indigenous marine species not previously known to be in New Zealand of 3.78 species per year, on average around 30% might be considered of major biosecurity risk.

Table 12 Introduction rates – all species

Average number of non-indigenous marine species not previously known to be in New Zealand, to two decimal places

Year	0 2012	1 2013	2 2014	3 2015	4 2016	5 2017	6 2018	7 2019	8 2020	9 2021	10+ 2022+
Scenario V (voluntary standards in Australia and California)											
Baseline scenario (voluntary standard)	3.78	3.63	3.39	3.20	3.06	2.94	2.83	2.72	2.63	2.54	2.46
Proposed IHS	3.78	3.52	3.24	2.99	2.80	2.62	2.40	2.22	2.05	1.90	1.76
Scenario M (mandatory standards in Australia and California)											
Baseline scenario (voluntary standard)	3.78	3.61	3.30	3.01	2.68	2.40	2.19	2.01	1.86	1.68	1.58
Proposed IHS	3.78	3.52	3.21	2.92	2.60	2.33	2.08	1.85	1.64	1.43	1.26

Source: Modelled by MPI, August 2012

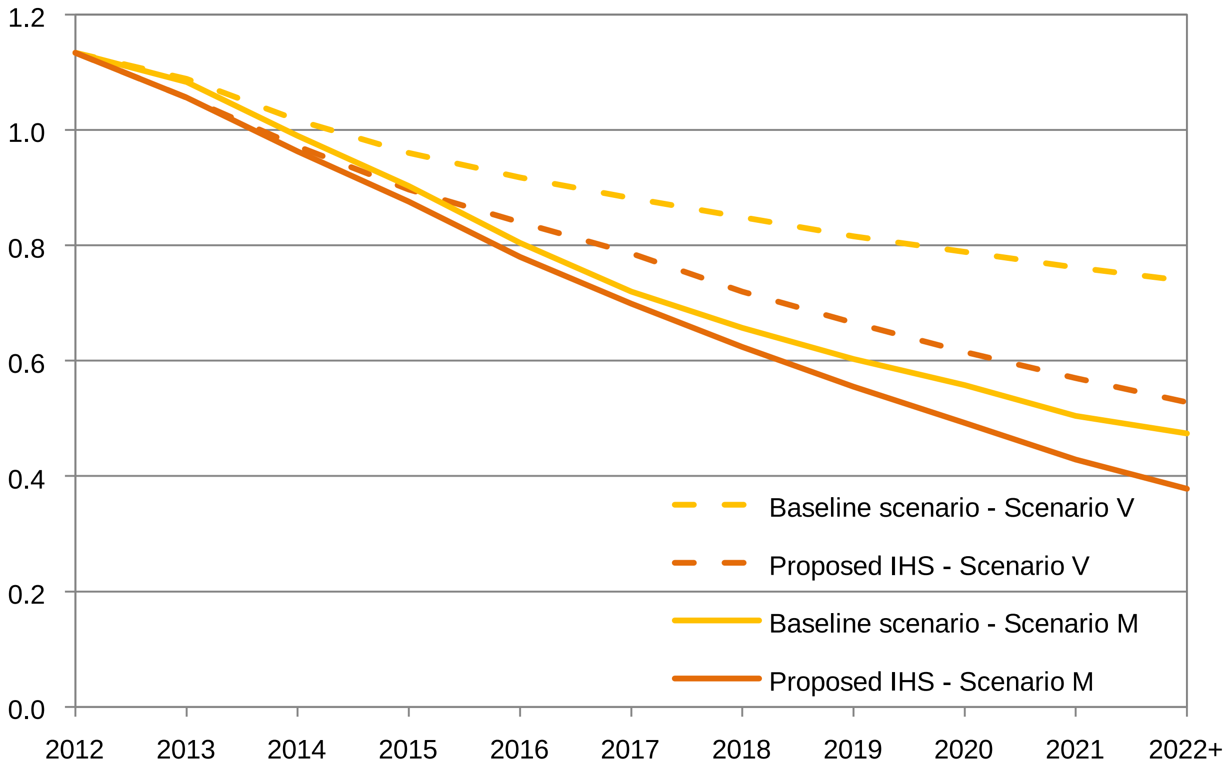
Table 13 Introduction rates - species of major biosecurity risk

Average number of non-indigenous species not previously known to be in New Zealand, to two decimal places

Year	0 2012	1 2013	2 2014	3 2015	4 2016	5 2017	6 2018	7 2019	8 2020	9 2021	10+ 2022+
Year	**0 2012**	**1 2013**	**2 2014**	**3 2015**	**4 2016**	**5 2017**	**6 2018**	**7 2019**	**8 2020**	**9 2021**	**10+ 2022+**
Scenario V (voluntary standards in Australia and California)											
Baseline scenario (voluntary standard)	1.13	1.09	1.02	0.96	0.92	0.88	0.85	0.82	0.79	0.76	0.74
Proposed IHS	1.13	1.06	0.97	0.90	0.84	0.79	0.72	0.67	0.62	0.57	0.53
Scenario M (mandatory standards in Australia and California)											
Baseline scenario (voluntary standard)	1.13	1.08	0.99	0.90	0.80	0.72	0.66	0.60	0.56	0.50	0.47
Proposed IHS	1.13	1.06	0.96	0.88	0.78	0.70	0.62	0.56	0.49	0.43	0.38

Assuming that the rates of introduction of species of major biosecurity risk remain proportionate, at 30%, to the rates of introduction of all species, the proposed IHS and the voluntary standard would reduce the rates of introduction of new species of major biosecurity risk as shown in Table 13 above and Figure 4. We consider the effect of lower or higher introduction rates in the sensitivity analysis of Section 3.4 below.

Figure 4 Introduction rates – species of major biosecurity risk
Average number of non-indigenous marine species not previously known to be in New Zealand



As shown in Figure 4, introduction rates would decline over time as the rates of vessel compliance with the proposed IHS or voluntary standard increased. The lower introduction rates under mandatory standards in Australia and California (Scenario M) than if their standards were voluntary (Scenario V) reflect higher compliance rates, to the extent that vessels arriving in New Zealand also visited these jurisdictions and already complied with their standards. Under both of these international scenarios, introduction rates would be lower under the proposed IHS than the baseline scenario's voluntary standard due to the higher compliance rates achieved. In assessing the benefits of the proposed IHS relative to the baseline scenario, however, we are again interested in the *difference* in introduction rates – how many *fewer* species would be introduced under the proposed IHS than the voluntary standard. As can be seen in Figure 4, the proposed IHS would achieve a smaller reduction in number of species introduced if Australia and California had mandatory standards and make a greater difference if their standards were only voluntary.

Table 14 shows how many fewer species would be introduced under the proposed IHS (introduction rates under the voluntary standard minus introduction rates under the proposed IHS).

Table 14 Reduction in introduction rates under proposed IHS – species of major biosecurity risk
Difference in average number of non-indigenous marine species not previously known to be in New Zealand, to two decimal places

Year	**0** **2012**	**1** **2013**	**2** **2014**	**3** **2015**	**4** **2016**	**5** **2017**	**6** **2018**	**7** **2019**	**8** **2020**	**9** **2021**	**10+** **2022+**
Scenario V (voluntary standards in Australia and California)		0.03	0.04	0.06	0.08	0.10	0.13	0.15	0.17	0.19	0.21
Scenario M (mandatory standards in Australia and California)		0.03	0.03	0.03	0.02	0.02	0 .03	0.05	0.07	0.08	0.10

2.7.2 Impacts on initial incursion response

When an incursion of a biosecurity risk organism is suspected, MPI launches an initial incursion response to identify the organism, to delimit its spread and to assess its impacts and the response options. This investigation phase incurs costs even if its conclusion is not to implement any subsequent response.

Table 15 shows MPI's expenditure on the seven major marine incursions that occurred over the six years 2005/06 to 2010/11 inclusive (provided by MPI, updated to 2012 prices).

Table 15 MPI expenditure on recent major marine incursion responses
$ million, in 2012 prices

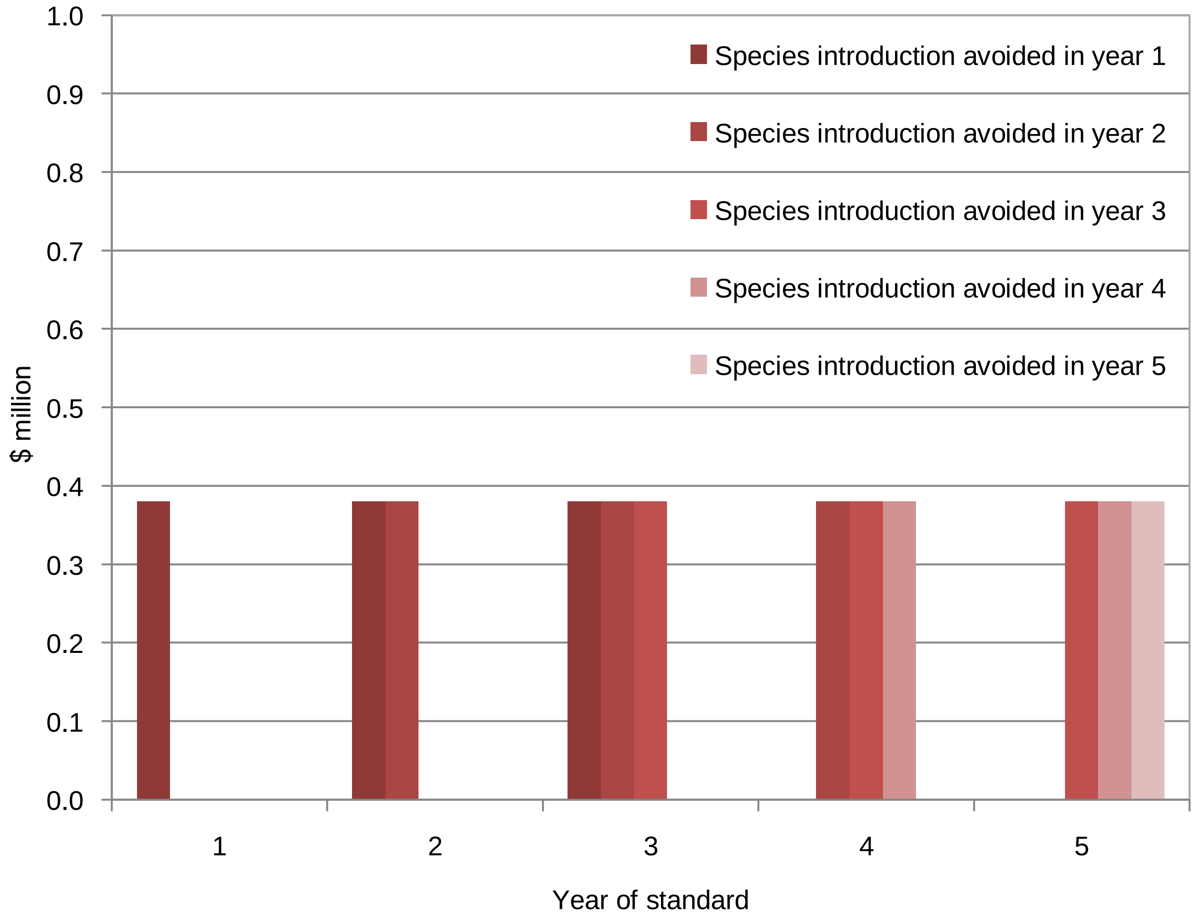
Incursion	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	Incursion total
Styela clava	1.279	1.134	0.588	0.004			3.005
Didemnum vexillum		0.196	0.183	0.174			0.553
Eudistoma elongatum		0.002	0.154				0.156
Sabella spallanzanii			0.207	0.644	0.678		1.530
Perna perna			0.499				0.499
Pyura praeputialis					0.143	0.093	0.237
Undaria pinnatifida						0.141	0.141
Annual total	1.279	1.332	1.631	0.823	0.821	0.235	6.121

Source: MPI, April 2012

Excluding *Pyura praeputialis* and *Undaria pinnatifida*, which incurred further expenditure after 2010/11, Table 15 suggests average expenditure per incursion of around $1.150 million, spread over two to four years. For some incursions, the expenditure shown above may include more than just the costs of the investigation phase. For example, the expenditure shown for *Sabella spallanzanii* includes the costs of an attempt at eradication until this was abandoned. Nevertheless, we use the above as indicative of average expenditure on an initial incursion response, which we therefore model as averaging $380,000 per year for each of three years.

For each one less species introduced in a given year, MPI would avoid three years expenditure on an initial incursion response, and would do so for each one less species introduced in each year of the proposed IHS or voluntary standard. The expenditure avoided is therefore additive with each additional species introduction avoided with each additional year. For example, one less species introduced in the first year of the standard would avoid three years expenditure on an initial incursion response to this introduction – $380,000 in year 1 of the standard, $380,000 in year 2 and $380,000 in year 3. Then one less species introduced in the second year would avoid three years expenditure on an initial incursion response to *this* introduction – $380,000 in year 2 of the standard, $380,000 in year 3 and $380,000 in year 4. And one less species introduced in the third year of the standard would avoid three years expenditure on an initial incursion response to *this* introduction – $380,000 in year 3 of the standard, $380,000 in year 4 and $380,000 in year 5. Therefore, in the third year of the standard, the total expenditure avoided on initial incursion responses would be $380,000 x 3 – the third year of expenditure on the introduction avoided in year 1, the second year of expenditure on the introduction avoided in year 2 and the first year of expenditure on the introduction avoided in year 3, as illustrated in Figure 5.

Figure 5 Expenditure avoided per species introduction avoided
Shows first five years only



It is not the total expenditure avoided that we are interested in, however, but the difference in total expenditure avoided between the proposed IHS and the baseline scenario's voluntary standard. We therefore apply the reduction in introduction rates of Table 14 above to average expenditure on initial incursion response to model how much less would be spent (i.e. how much would be saved) on investigation of incursions each year under the proposed IHS than under the voluntary standard.

2.7.3 Impacts on aquaculture

This initial incursion response expenditure alone would not prevent impacts on affected sectors. Given the difficulty of eradicating or containing introduced species in the marine environment, once a species has been introduced, there are often no feasible and practical response options available. We therefore also model impacts on affected sectors as introduced species spread.

One sector that is particularly vulnerable to impacts from new non-indigenous species introduced as biofouling on vessels is aquaculture. We model the benefits to aquaculture of the proposed IHS, relative to the baseline scenario's voluntary standard, in terms of the potential impacts on aquaculture of introduced species and the extent to which these impacts might be avoided by reducing the rate of introduction of new species.

Aquaculture sector

Over 19,200 hectares of New Zealand's coastline has been allocated as aquaculture space. To date, over 7,700 hectares of this has been granted to the aquaculture sector with a right to farm for a defined term (as at December 2011, Aquaculture New Zealand, 2012). The latest available statistics report that the three largest aquaculture fisheries – Greenshell mussels, Pacific oysters and king salmon – currently cover a total of 6,250 hectares and earn over $406 million in revenue from export and domestic markets. The king salmon fishery covers the smallest area of the three, but earns the highest average revenue per hectare.

Table 16 Aquaculture sector

Statistic	Greenshell mussels	Pacific oysters	King salmon
Area (ha)	5,250	900	100
Annual revenue ($ million)	253.1	24.6	128.4
Average revenue per hectare per year ($)	48,210	27,333	1,284,000
Average value added per hectare per year ($)	26,515	15,033	706,200

Source: Coriolis (2012) for area in 2010, Aquaculture New Zealand (2012) for export and domestic revenue in year to December 2011 (domestic revenue is estimated due to lack of robust domestic market information)

The aquaculture sector has grown rapidly over the past 25 years and set a revenue goal of $1 billion per year by 2025 (New Zealand Aquaculture Council, 2006). If this goal is in "real" terms (net of inflation), as expressed in the 2006 strategy, to achieve it would require real average growth of 7% per year over 2012 to 2025 (or real average growth of 5% per year, if the revenue goal is now nominal (including inflation) and inflation averages 2%). This might be achieved by a combination of increased area and increased revenue per hectare. For the purpose of incorporating into the CBA the impact of introduced species on the future expansion of the sector, we assume that this goal is achieved. We consider the effect of weaker or stronger growth rates in the sensitivity analysis of Section 3.4 below.

In assessing the impacts of introduced species on the aquaculture sector, however, we are interested in not so much the loss of revenue as the loss of "value added" – the surplus of revenue earned from outputs over the cost of buying in inputs. For the mussel industry, the "value added" has been estimated to average around 55% of revenue (Philip Donnelly & Associates, 1999). This estimate dates from 1999, but more recent estimates have focused on individual regions and not the national industry. We use this estimate for consistency across regions and adopt it as broadly indicative of the value added for oysters and salmon also, in deriving average value added per hectare, as shown in Table 16 above.

Introduced species

MPI has completed a comprehensive risk analysis of the biosecurity risks associated with biofouling organisms on the hulls of vessels arriving in New Zealand from international waters (Ministry of Agriculture and Forestry, 2011). This risk analysis assessed 20 broad taxonomic groups and determined 12 of these groups to contain species that present nonnegligible risks to New Zealand's core values:

- amphipods and isopods,
- barnacles,
- bivalves,
- bristleworms,
- bryozoans,
- crabs,
- echinoderms,
- flatworms,
- gastropods,
- hydroids,
- macroalgae and
- sea squirts.

We cannot predict with certainty which species would be introduced, nor when. For the purpose of this CBA, we model the potential impacts on aquaculture and other affected sectors of a sample of 14 species that are considered to be of major biosecurity risk due to their ability to establish in and impact on New Zealand's marine environment:

- four seas squirts Didemnum vexillum, Eudistoma elongatum, Pyura praeputialis and Styela clava
- the brown mussel Perna perna
- the Asian clam Potamocorbula amurensis
- the skeleton shrimp Caprella mutica

- the Mediterranean fanworm Sabella spallanzanii
- the North Pacific sea star Asterias amurensis
- the European green crab Carcinus maenas
- two kelps Undaria pinnatifida and Sargassum muticum
- a tubeworm (generic) and
- a bryozoan (generic encrusting).

Although several of these species have already been introduced and become established in New Zealand (the four sea squirts, *Sabella spallanzanii* and *Undaria pinnatifida*), MPI considers that the 14 species listed above can be used as representative of the types of new species that could be introduced by vessel biofouling in the future and the impacts of which might therefore be avoided by reducing introduction rates through improved biofouling management.

Impacts on production

MPI has examined the impacts of each of these 14 species on the three largest aquaculture fisheries and, for the purpose of the CBA, suggests the approximate average impacts on production shown in Table 17. These impacts are measured in terms of reduction in value added per hectare and reflect the combination of reduced output and/or increased costs, including the additional costs of measures adopted to mitigate the reduction in output suffered. We consider the effect of smaller or larger production impacts in the sensitivity analysis of Section 3.4 below.

Table 17 Impacts on production

Percentage reduction in value added per hectare

Introduced species	Type of impact	Greenshell mussels	Pacific oysters	King salmon
Didemnum vexillum	Production loss and nuisance fouling	30%	0%	10%
Eudistoma elongatum	Production loss and nuisance fouling	10%	5%	0%
Pyura praeputialis	None	0%	0%	0%
Styela clava	Nuisance fouling	5%	5%	0%
Perna perna	Production loss and export market loss	10%	0%	0%
Potamocorbula amurensis	Production loss	30%	5%	0%
Caprella mutica	Nuisance fouling	5%	5%	10%
Sabella spallanzanii	Production loss and nuisance fouling	10%	10%	0%
Asterias amurensis	Production loss	35%	20%	0%
Carcinus maenas	Production loss	20%	20%	0%
Undaria pinnatifida	Nuisance fouling	5%	5%	0%
Sargassum muticum	Production loss and nuisance fouling	5%	35%	0%
Tubeworm	Nuisance fouling	5%	5%	0%
Bryozoan	None	0%	0%	0%

Source: MPI, August 2012

Across the 14 introduced species, including species that would not affect aquaculture, Table 17 suggests an average impact of just over 7%.

Applying the reductions in value added of Table 17 to the average value added per hectare of Table 16 indicates an average reduction in value added per hectare of between $0 for species that would not affect aquaculture and almost $71,000 per hectare for introduced species that affect king salmon, which although not the worst affected fishery in volume terms, produces the highest value of output per hectare.

Table 18 Average impacts per hectare per year
$, in 2012 prices

Introduced species	Greenshell mussels	Pacific oysters	King salmon
Didemnum vexillum	7,955	0	70,620
Eudistoma elongatum	2,652	752	0
Pyura praeputialis	0	0	0
Styela clava	1,326	752	0
Perna perna	2,652	0	0
Potamocorbula amurensis	7,955	752	0
Caprella mutica	1,326	752	70,620
Sabella spallanzanii	2,652	1,503	0
Asterias amurensis	9,280	3,007	0
Carcinus maenas	5,303	3,007	0
Undaria pinnatifida	1,326	752	0
Sargassum muticum	1,326	5,262	0
Tubeworm	1,326	752	0
Bryozoan	0	0	0

MPI advises that these introduced species could spread to all aquaculture areas around New Zealand. Across the total areas of the three aquaculture fisheries modelled, the impacts per hectare of Table 18 above imply total impacts on the aquaculture sector of between $0 for species that would not affect aquaculture and around $124 million per year for *Asterias amurensis,* once the introduced species had completed their spread (i.e. the ongoing annual impacts). Note that because we have incorporated the aquaculture sector growing by 7% per year to reach its $1 billion revenue goal by 2025, these total impacts include impacts on the anticipated increase in area in production and/or revenue generated per hectare over the next 13 years.

Table 19 Total impacts per year when spread complete
$ million, in 2012 prices, including anticipated growth in aquaculture sector to 2025

Introduced species	Greenshell mussels	Pacific oysters	King salmon	Total
Didemnum vexillum	100.6	0	17.0	117.7
Eudistoma elongatum	33.5	1.6	0	35.2
Pyura praeputialis	0	0	0	0
Styela clava	16.8	1.6	0	18.4
Perna perna	33.5	0	0	33.5
Potamocorbula amurensis	100.6	1.6	0	102.3
Caprella mutica	16.8	1.6	17.0	35.4
Sabella spallanzanii	33.5	3.3	0	36.8
Asterias amurensis	117.4	6.5	0	123.9
Carcinus maenas	67.1	6.5	0	73.6
Undaria pinnatifida	16.8	1.6	0	18.4
Sargassum muticum	16.8	11.4	0	28.2
Tubeworm	16.8	1.6	0	18.4
Bryozoan	0	0	0	0

Note that, in modelling these impacts, we assume no price effects from reduced output, given that most of the output of the aquaculture sector is exported. Otherwise, a drop in output could push up the price received for remaining output, such that impacts would be smaller than those modelled above. Impacts could be larger than those modelled above, at least in the short run, if the introduction of a new species affected export market access, such as if a high price market was closed to New Zealand on grounds of biosecurity or food safety. In this event, the aquaculture sector, with the help of government officials, would seek to negotiate resumption of market access as soon as possible, which may require implementation of additional measures to manage the biosecurity or food safety risk. If this could not be achieved, the aquaculture sector may have to develop alternative markets or, ultimately, switch to farming different species.

If multiple species were introduced, the sum of their impacts could be smaller or larger than modelled above depending on the cumulative impacts of these species in combination. For example, two introduced species together may have smaller impacts than the sum of their impacts independently if they would compete with each other for habitat or food sources or if the measures adopted by aquaculture to mitigate the reduction in output from the first species introduced would also mitigate the reduction in output from the second. Alternatively, the impacts could be larger if the species already introduced had already weakened the financial or even biological viability of some aquaculture farms to the point where they could not survive the introduction of a further species, even if this species independently would have only relatively small impacts.

There might also possibly, over the longer run, be some positive impacts if there were opportunities to earn revenue from harvesting or farming some of the introduced species, but we have not included any in this CBA.

Rates of spread

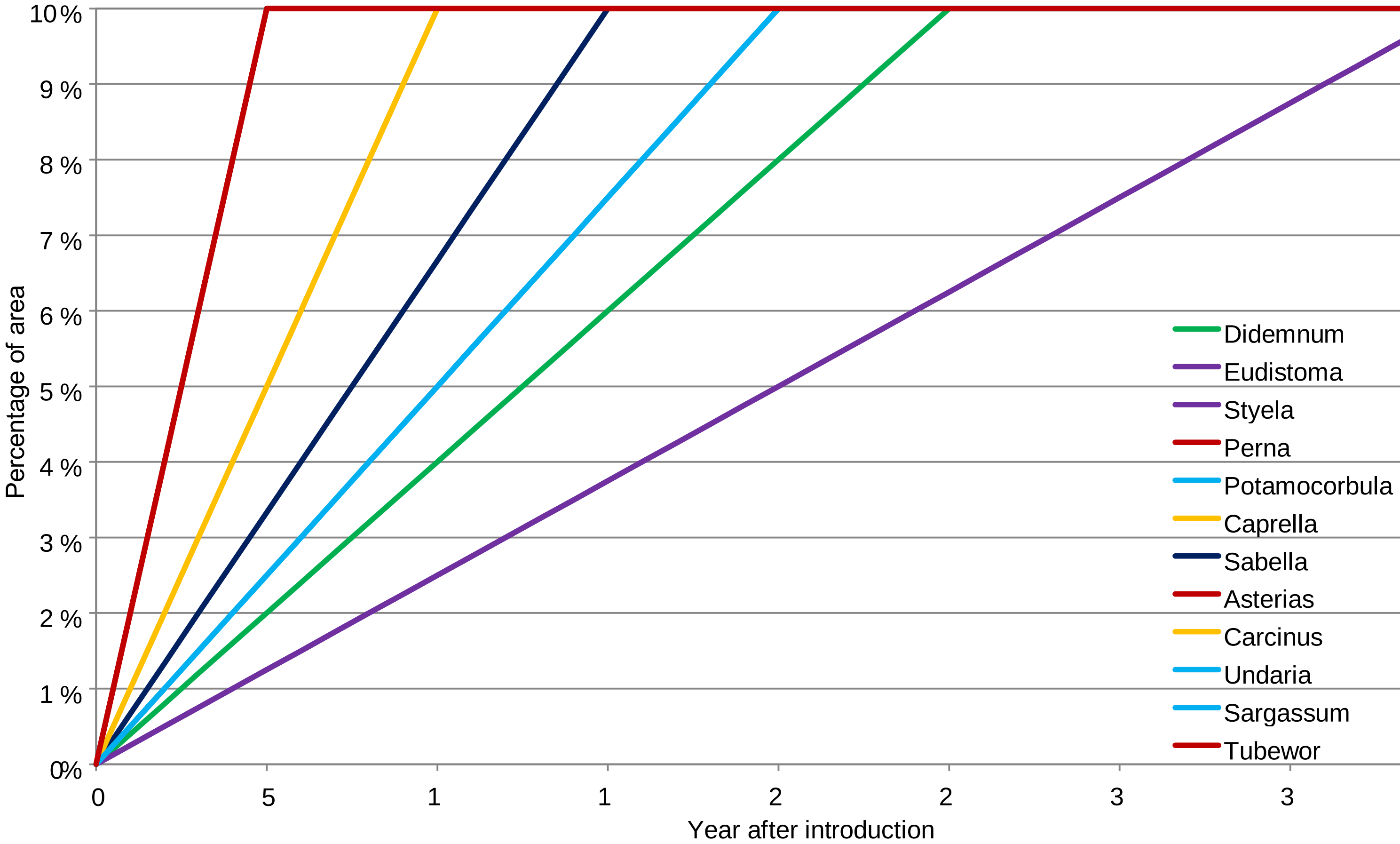
It would, however, take time for the introduced species to spread to all aquaculture areas and therefore to reach the level of impacts shown in Table 19 above. MPI has explored the potential rates of spread of these species in the New Zealand environment. For the purpose of the CBA, MPI suggests the most likely approximate rates of spread in aquaculture shown in Table 20. We consider the effect of slower or faster rates of spread in the sensitivity analysis of Section 3.4 below.

Table 20 Table 20. Time to complete spread in aquaculture areas

Introduced species	Years
Didemnum vexillum	25
Eudistoma elongatum	40
Pyura praeputialis	
Styela clava	40
Perna perna	5
Potamocorbula amurensis	20
Caprella mutica	10
Sabella spallanzanii	15
Asterias amurensis	5
Carcinus maenas	10
Undaria pinnatifida	20
Sargassum muticum	20
Tubeworm	5
Bryozoan	

Source: MPI, August 2012

Figure 6 Spread of introduced species in aquaculture

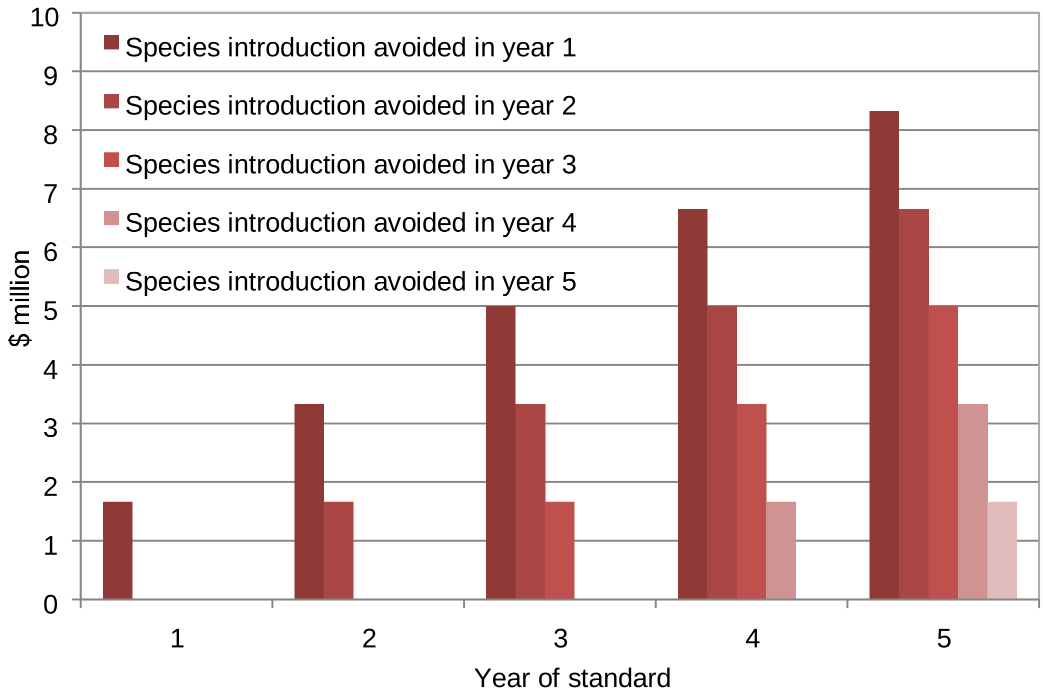


MPI has also explored various patterns of spread, including adopting different patterns of spread for different introduced species, but concluded that modelling a linear increase in affected area for each introduced species is likely to be as accurate as any other pattern of spread. Using this pattern and the above rates of spread, Figure 6 above shows how much of the three aquaculture fisheries is modelled as affected by each introduced species in each year following introduction.

Impacts avoided by reducing introduction rates

For each one less species introduced in a given year, the aquaculture sector would avoid the impacts of this species in all subsequent years, as it would have gradually spread throughout New Zealand, and would do so for each one less species introduced in each additional year of the proposed IHS or voluntary standard. The impacts avoided are therefore additive with each additional species introduction avoided with each additional year. For example, for each one less species introduced in the first year of the standard, the aquaculture sector would avoid all future years of impacts of this introduction. Then one less species introduced in the second year would avoid all future years of impacts of *this* introduction. And one less species introduced in the third year of the standard would avoid all future years of impacts of *this* introduction. Therefore, in the third year of the standard, the total impacts avoided would be the third year of impacts of the introduction avoided in year 1, the second year of impacts of the introduction avoided in year 2 and the first year of impacts of the introduction avoided in year 3, as illustrated in Figure 7.

Figure 7 Impacts avoided per species introduction avoided
Illustrative example, shows first five years only



The magnitude of these impacts would depend on which species were prevented from being introduced in which years. As noted above, we cannot predict with certainty which species would be introduced, when, and model the selected 14 species as representative of the types of new species that could be introduced by vessel biofouling. We therefore use the average impact, in each year following introduction, across these 14 species, treating each of the 14 species as equally likely of introduction.

It is not the total impacts avoided that we are interested in, however, but the difference in total impacts avoided between the proposed IHS and the baseline scenario's voluntary standard. We therefore apply the reduction in introduction rates of Table 14 above to this average impact per species over subsequent years, to model how much smaller the total impacts would be (i.e. how much would be avoided) in each year under the proposed IHS than under the voluntary standard.

2.7.4 Impacts on commercial fishing

We use a similar approach in modelling the benefits to commercial fishing of the proposed IHS, relative to the baseline scenario's voluntary standard, in terms of the potential impacts of introduced species on commercial fishing and the extent to which these impacts might be avoided by reducing the rate of introduction of new species.

Commercial fishing sector

We use the same 14 introduced species, representative of the types of new species that could be introduced by vessel biofouling, as for potential impacts on aquaculture.

Commercial fishing is, however, less vulnerable to these introduced species than aquaculture. Of the fish species that are commercially caught in New Zealand (Ministry for Primary Industries, 2012), MPI's risk analysis (Ministry of Agriculture and Forestry, 2011) mentions several that may be significantly affected by species that could be introduced as biofouling on vessels. These include snapper, cod, paua, kina/sea urchin/sea egg, paddle crab, mussel, scallop, oyster, whelk and anchovy. In the year to September 2010 (the last year for which data are complete), the reported catches of these species totalled almost 13,800 tonnes (Ministry for Primary Industries, 2012). Of this total, reported catches of snapper, red cod and black and yellowfoot paua accounted for 91% (but only 3% of the total annual catch across all species). We therefore model the potential impacts of introduced species on these three commercially fished species.

Table 21 Commercial fishing sector

Statistic	Snapper	Red cod	Paua
Annual catch (tonnes)	6,229	5,236	1,010
Asset value ($ million)	276.4	13.8	320.7
Annual value added ($ million)	24.9	1.2	28.9

As for aquaculture, in assessing the impacts of introduced species on these fisheries, we are interested in not so much the loss of revenue as the loss of "value added" – the surplus of revenue earned from outputs over the cost of buying in inputs. Following Schischka and Marsh (2008) in Kerr and Latham (2011), we estimate the annual valued added of these fisheries from the market value of their quota, which reflects the expected future stream of returns to owning quota, converted to an annual value by capitalising at a rate of 9%. We use the asset values of Statistics New Zealand (2010), which are based on quota and annual catch entitlement values. These asset values fluctuate from year to year, but we update 2009 asset values to 2012 based on average growth in total asset value of 1.8% per year.

Impacts on production

MPI has examined the impacts of each of the 14 introduced species on these three commercial fisheries and, for the purpose of the CBA, suggests the approximate average impacts on production shown in Table 22. These impacts are measured in terms of reduction in value added and reflect the combination of reduced catch and/or increased costs, including the additional costs of measures adopted to mitigate the reduction in catch suffered. We consider the effect of smaller or larger production impacts in the sensitivity analysis of Section 3.4 below.

Table 22 Impacts on production

Introduced species	Snapper	Red cod	Paua
Didemnum vexillum	0%	5%	0%
Eudistoma elongatum	0%	0%	0%
Pyura praeputialis	0%	0%	0%
Styela clava	0%	0%	0%
Perna perna	0%	0%	0%
Potamocorbula amurensis	0%	0%	0%
Caprella mutica	0%	0%	0%

Sabella spallanzanii	0%	0%	0%
Asterias amurensis	0%	0%	0%
Carcinus maenas	0%	0%	0%
Undaria pinnatifida	0%	0%	0%
Sargassum muticum	0%	0%	15%
Tubeworm	0%	0%	0%
Bryozoan	45%	0%	0%

Source: MPI, August 2012

In terms of impacts on fish populations, MPI advises that the areas affected directly by these introduced species would comprise the area of nursery habitat for snapper in the Kaipara Harbour (25,000 hectares), the area of continental shelf hotspots for juvenile red cod (750,000 hectares) and the total area over which paua is harvested (220,000 hectares). The production impacts shown above reflect that reduced numbers of juvenile fish would ultimately affect mature fish populations and therefore catches.

Applying the reductions in value added of Table 22 to the annual value added of each fishery of Table 21 indicates total impacts on the commercial fishing sector of between $0 for species that would not affect commercial fishing and around $11 million per year for bryozoan, once the introduced species had completed their spread throughout the affected areas of these fisheries (i.e. the ongoing annual impacts).

Table 23 Total impacts per year when spread complete
$ million, in 2012 prices

Introduced species	Snapper	Red cod	Paua	Total
Didemnum vexillum	0	0.062	0	0.062
Eudistoma elongatum	0	0	0	0
Pyura praeputialis	0	0	0	0
Styela clava	0	0	0	0
Perna perna	0	0	0	0
Potamocorbula amurensis	0	0	0	0
Caprella mutica	0	0	0	0
Sabella spallanzanii	0	0	0	0
Asterias amurensis	0	0	0	0
Carcinus maenas	0	0	0	0
Undaria pinnatifida	0	0	0	0
Sargassum muticum	0	0	4.3	4.3
Tubeworm	0	0	0	0
Bryozoan	11.2	0	0	11.2

Like aquaculture, in modelling these impacts, we assume no price effects from reduced catches, given that most of the fish caught are exported. Impacts could be larger than those modelled above if the introduction of a new species affected export market access. Where multiple species are introduced, the sum of their impacts could be smaller or larger depending on the cumulative impacts of these species in combination. There could again possibly also be some positive impacts from introduced species, such as if there was value in harvesting them or if they provided additional food sources for predator species.

Rates of spread

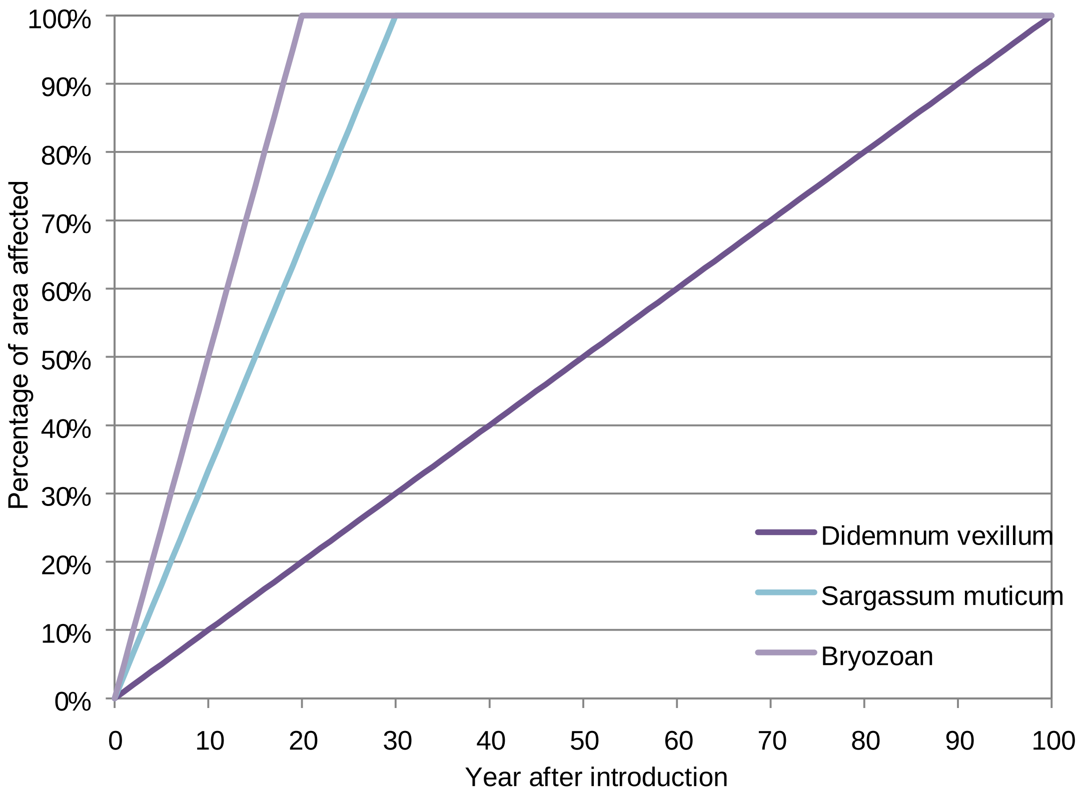
It would again take some time for the introduced species to complete their spread and therefore to reach the level of impacts shown in Table 23 above. For the purpose of the CBA, MPI suggests the most likely approximate rates of spread in commercial fishing shown in Table 24. MPI considers the sea squirt *Didemnum vexillum* likely to spread so slowly in the New Zealand environment that it would take around 100 years to spread throughout the continental shelf hotspots for juvenile red cod. We consider the effect of slower or faster rates of spread in the sensitivity analysis of Section 3.4 below.

Table 24 Time to complete spread in commercial fishing grounds

Introduced Species	Years
Didemnum vexillum	100
Eudistoma elongatum	0
Pyura praeputialis	0
Styela clava	0
Perna perna	0
Potamocorbula amurensis	0
Caprella mutica	0
Sabella spallanzanii	0
Asterias amurensis	0
Carcinus maenas	0
Undaria pinnatifida	0
Sargassum muticum	30
Tubeworm	0
Bryozoan	20

Source: MPI, August 2012

Figure 8 Spread of introduced species in commercial fishing



As for aquaculture, MPI considers that modelling a linear increase in affected area for each introduced species is likely to be as accurate as any other pattern of spread. Using this pattern and the above rates of spread, Figure 8 above shows how much of the three commercial fisheries is modelled as affected by each introduced species in each year following introduction.

Impacts avoided by reducing introduction rates

For each one less species introduced in a given year, the commercial fishing sector would avoid the impacts of this species in all subsequent years, as it would have gradually spread throughout New Zealand, and would do so for each one less species introduced in each additional year of the proposed IHS or voluntary standard. Like the avoided impacts on aquaculture, the avoided impacts on commercial fishing are therefore additive with each additional species introduction avoided with each additional year.

Again, the magnitude of these impacts would depend on which species were prevented from being introduced in which years. Indeed, if this was a species that does not affect commercial fishing, there would be no benefits to commercial fishing. As noted above, we cannot predict with certainty which species would be introduced, when, and we model the selected 14 species as representative of the types of new species that could be introduced by vessel biofouling. We therefore use the average impact, in each year following introduction, across these 14 species, treating each of the 14 species as equally likely of introduction.

It is again not the total impacts avoided that we are interested in, but the difference in total impacts avoided between the proposed IHS and the baseline scenario's voluntary standard. We therefore apply the reduction in introduction rates of Table 14 above to this average impact per species over subsequent years, to model how much smaller the total impacts would be (i.e. how much would be avoided) in each year under the proposed IHS than under the voluntary standard.

2.7.5 Distribution and spread in coastal environment

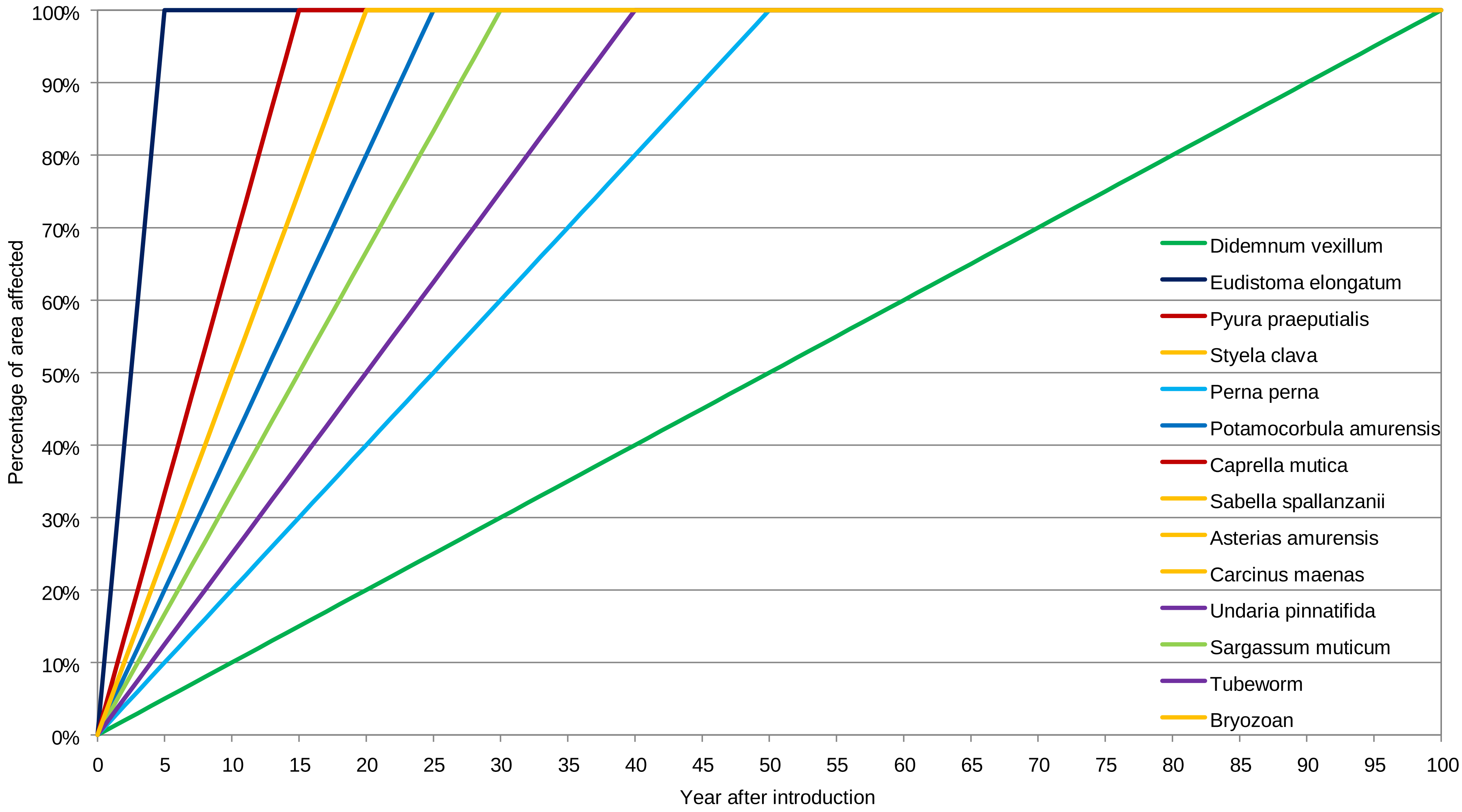
MPI has also examined how much of the coastal environment around New Zealand, within 10 kilometres of the shore, could provide suitable habitat for each of the 14 introduced species we model as representative of the types of new species that could be introduced by vessel biofouling and how long these species might take to spread throughout this habitat.

Table 25 Distribution and spread in coastal environment

Introduced species	**Suitable habitat**	**Years to complete spread**
Didemnum vexillum	75%	100
Eudistoma elongatum	5%	5
Pyura praeputialis	5%	15
Styela clava	40%	20
Perna perna	10%	50
Potamocorbula amurensis	25%	25
Caprella mutica	80%	15
Sabella spallanzanii	25%	20
Asterias amurensis	40%	20
Carcinus maenas	70%	20
Undaria pinnatifida	75%	40
Sargassum muticum	60%	30
Tubeworm	25%	40
Bryozoan	0.4%	20

Source: MPI, August 2012

Figure 9 Spread of introduced species in coastal environment



Across the 14 introduced species, Table 25 suggests that on average 38% of the coastal environment could provide suitable habitat.

Again adopting a linear pattern of spread for each species, Figure 9 above shows how much of the habitat suitable for each species is modelled as affected in each year following introduction.

We use this distribution and spread in modelling the avoided impacts of introduced species on activities in the coastal environment in Sections 2.7.6 to 2.7.12 below

2.7.6 Impacts on coastal infrastructure

New species introduced as biofouling on vessels may accumulate on not only cages and other structures in aquaculture and lines, nets and cages in commercial fishing, but also on marine structures at ports and other coastal infrastructure.

Ports and other coastal infrastructure already manage existing biofouling that could interfere with their function or use, including indigenous species. The introduction of new species could add to this biofouling and necessitate adoption of additional measures. These measures could include treating filters or nets with antifouling coatings or installing selfcleaning screens on water intakes, changing to different cooling systems, improving antifouling treatment of navigational buoys and other structures that can be removed from the water and increasing cleaning of wharves and other marine structures that are permanently submerged. Such measures would incur additional costs.

We model the impacts on coastal infrastructure in terms of additional biofouling management costs to ports. These additional costs are small relative to the potential impacts of introduced species on other sectors, but we include them in this CBA for completeness.

The Port of Tauranga currently spends around $8 million per year on maintenance of all port plant, machinery and equipment (Port of Tauranga, 2011). If management of existing biofouling accounted for around 1% of this total, it would cost around $80,000 per year.

How much these costs might increase with the introduction of new species by vessel biofouling would depend on the species introduced. In the absence of information on how much each species might increase biofouling management costs to ports, we adopt an average equivalent to the average impact on aquaculture production, 7% (from Table 17). A 7% increase in costs would amount to an additional $5,600 per year. Scaling this up across all ports, in proportion to Tauranga according to the relative volumes of imports and exports handled per year (around four times those of Tauranga, Statistics New Zealand, 2012a), suggests total additional costs nationally of around $22,400 per species introduced. To reflect the gradual spread around New Zealand's coastline, we take the average of the spread of the 14 introduced species in New Zealand's coastal environment from Figure 9 above, weighted by how much of the coastal environment could provide suitable habitat for each species.

For each one less species introduced in a given year, ports would avoid these additional biofouling management costs in all subsequent years, as it would have gradually spread around New Zealand, and would do so for each one less species introduced in each additional year of the proposed IHS or voluntary standard. Like the avoided impacts on aquaculture and commercial fishing, the costs avoided are therefore additive with each additional species introduction avoided with each additional year. To derive the difference in total costs avoided between the proposed IHS and the baseline scenario's voluntary standard, we apply the reduction in introduction rates of Table 14 above to the average additional costs per species over subsequent years, to model how much smaller the total costs would be (i.e. how much would be avoided) in each year under the proposed IHS than under the voluntary standard.

2.7.7 Impacts on marine tourism and recreation

We use a similar approach to that used above for aquaculture and commercial fishing in modelling the avoided impacts of introduced species on various recreational uses of the coastal environment, but more simplified due to data limitations and time constraints for this CBA.

A recent study of tourist participation in nature-based activities suggests that around 70% of international visitors and 22% of domestic visitors (including multiple visits per year, but excluding visits by local residents) participate in nature-based activities (Ministry of Tourism, 2009). Many of these activities are on land or on/in lakes and rivers. An earlier study suggests that 62% of international visitors participate in marine activities whilst in New Zealand (Statistics New Zealand, 2006). Spending on marine tourism and recreation is estimated to have contributed 0.04% to the New Zealand economy in 2002 (Statistics New Zealand, 2006). This encompassed spending on recreational fishing, coastal and marine tourism, cruise ships, leisure craft services, marinas and marine equipment retailing and also captured restaurants, lodgings, and recreation services dependent on the marine environment for their operations. If this contribution has remained broadly constant, it now equates to around $89 million per year (applied to gross domestic product for the year to December 2011, Statistics New Zealand 2012c).

How much of New Zealand's marine tourism and recreation would be affected by species introduced as biofouling on vessels would depend on which species was introduced. As we cannot predict this, we again treat each of the 14 species we model as representative of the types of new species that could be introduced by vessel biofouling as equally likely of introduction. Based on how much of New Zealand's coastal environment could provide suitable habitat for each species, from Table 25 above, we assume that on average 38% of marine tourism and recreation activities might be affected. This proportion could be higher if the species introduced affected areas popular for marine tourism and recreation or lower if the species introduced affected remote or little used areas.

How severely these marine tourism and recreation activities might be affected would also depend on which species was introduced. In the absence of information on how much each of the 14 introduced species modelled might affect the quality of the marine environment used for tourism and recreation activities, we adopt the average impact on aquaculture production as broadly indicative. Like the majority of marine tourism and recreation activities, aquaculture occurs relatively close to shore. The "natural" environment in which these activities occur is more diverse, so may be more resilient, but is also less protected than the semi-controlled environment of aquaculture. Table 17 above implies an average reduction of around 7%. This 7% includes the likely responses of affected sectors as they change their behaviour to mitigate the impacts to which they are exposed. In this case, for example, some visitors may switch to less affected locations or activities.

In this case, there is the added complication of how much a reduction in the quality of the marine environment would reduce the quality of the experience and enjoyment derived from tourism and recreation activities in this environment. For example, how much would the presence of introduced species and a reduction in other marine life affect tourists' enjoyment of and therefore demand for fishing, scuba diving, surfing, kayaking and other water sports, or even whale watching, swimming with dolphins and visiting seal and penguin colonies, if these species are significantly affected by the impacts of introduced species on ecosystems and food chains. For the purpose of the CBA, we make the very simple assumption that, of the 7% reduction in quality of the marine environment used for tourism and recreation activities, only around one fifth would translate into a loss of expenditure on these activities.
By way of illustration this could represent, for example, of every five visitors who suffer this 7% reduction in quality of the marine environment for tourism and recreation activities, one visitor reduces his/her expenditure by an equivalent 7%, or, alternatively, two reduce their expenditure by half as much, 3.5%, or four reduce their expenditure by a quarter as much, 1.75%, due to the impacts of the introduced species.

The combination of the above assumptions suggests that, by the time an introduced species completed its spread around New Zealand, it could be reducing the contribution of marine tourism and recreation expenditure to the economy by, on average, around $0.5 million per year (one fifth of 7% of 38% of $89 million). We consider the effect of smaller or larger impacts in the sensitivity analysis of Section 3.4 below. To model its gradual spread around New Zealand's coastline, we adopt the weighted average of the spread of the 14 introduced species in New Zealand's coastal environment from Figure 9 above.

For each one less species introduced in a given year, we would avoid the impact of this species on the contribution of marine tourism and recreation expenditure to the economy in all subsequent years, as it would have gradually spread around New Zealand, and would do so for each one less species introduced in each additional year of the proposed IHS or voluntary standard. The impacts avoided are therefore additive with each additional species introduction avoided with each additional year. To derive the difference in total impacts avoided between the proposed IHS and the baseline scenario's voluntary standard, we apply the reduction in introduction rates of Table 14 above to the average impact per species over subsequent years, to model how much smaller the total impacts would be (i.e. how much would be avoided) in each year under the proposed IHS than under the voluntary standard.

2.7.8 Impacts on recreational fishing

Expenditure on marine tourism and recreation does not, however, capture the full value of these activities. Not only does it exclude the value of recreational uses of the sea and seashore that do not incur any additional expenditure (e.g. once marine equipment is purchased, it may be used multiple times). More importantly, participants may value their enjoyment of these activities over and above solely the financial cost and would lose these values if they had to curtail these activities due to the introduction of new species.

Non-market valuation

We therefore also consider these "non-market values" associated with recreational uses of the sea and seashore. These values cannot be observed directly, but may be elicited through non-market valuation methods. These methods seek to measure what society would be willing to pay to secure a positive impact or to prevent a negative impact or, alternatively, willing to accept in compensation for forgoing a positive impact or tolerating a negative impact. Non-market values are therefore able to incorporate psychological factors such as amenity and aesthetic attributes and levels of inconvenience, annoyance, discomfort or distress. Non-market values may comprise not only current use value, but also option value – the value placed on retaining the option to use a resource, including for purposes yet unknown, in future years or providing for its use by others (vicarious benefit) or future generations (bequest value) – and existence value – the value placed on the continued existence of an resource, independent of its present or anticipated use – which may be particularly important for environmental, social and cultural resources.

There are two categories of methods for eliciting willingness-to-pay where market values do not exist – revealed preference methods and stated preference methods. Revealed preference methods seek to derive willingness-to-pay from transactions in related markets. One of these, which might be applicable for some recreational uses of the sea and seashore, is the travel cost method, which examines the relationship between visits to recreation sites of different qualities or attributes and differences in the travel costs, including travel time, associated with these visits.

Stated preference methods involve surveying representative groups using carefully framed questionnaires or interviews to identify respondents' preferences in trading off costs and benefits, including reductions in risk, under a range of scenarios – in effect, simulating hypothetical markets. Such surveys can be expensive and time consuming to conduct and require careful question design, sample selection and interpretation of responses if reliable estimates are to be obtained. The extrapolation of results to the national level can generate very large totals, the validity of which may be questionable. Often, briefing material must be supplied to enable respondents to make informed choices, but some impacts, such as those on marine organisms and ecosystems, may be too remote or too poorly understood by respondents for meaningful estimates of willingness-to-pay to be derived.

Impacts on recreational fishing

The first non-market value we consider is that of recreational fishing. Ideally, we would use willingness-to-pay to prevent the change in condition of the recreational fishery that would be caused by each of the 14 introduced species we model as representative of the types of new species that could be introduced by vessel biofouling. Given the expense and time involved in undertaking robust stated preference surveys, for the purpose of this CBA we make use of the findings of previous studies on the non-market value of recreational fishing.

Based on Schischka and Marsh (2008), we adopt an average consumer surplus per recreational fisher per fishing trip of $62 (mid-range, updated to 2012 prices). Consumer surplus represents the surplus of willingness-to-pay over the financial cost fishers actually pay, so ensures that we are not double counting the expenditure modelled in Section 2.7.7 above. Estimates of the number of New Zealanders who participate in recreational fishing range from around 500,000 (SPARC, 2009) to over one million (NIWA, 2007). We adopt the mid-range of 750,000. The average number of fishing trips per fisher per year ranges from 8.6 (Davey *et al*., 2006) to 9.3 (Schischka and Marsh, 2008). We assume nine. Combining these assumptions implies a total national consumer surplus from recreational fishing of around $419 million per year.

NIWA has a number of recreational fishing surveys and other research projects underway, commissioned by MPI, to improve recreational catch estimates. Historically, the five main recreational fish species have been snapper, kingfish, blue cod, kahawai and rock lobster (South Australian Centre for Economic Studies, 1999). How much of New Zealand's recreational fishing might be affected by species introduced as biofouling on vessels would depend on which species was introduced. Again, we treat each of the 14 species we model as equally likely of introduction. Based on how much of New Zealand's coastal environment could provide suitable habitat for each species, for the purpose of this CBA we assume that on average 38% of recreational fishing might be affected by introduced species, either directly by their presence (e.g. additional biofouling of fishing lines, nets, cages, ropes and moorings or harm from physical contact) or through their impacts on populations of recreationally fished species. This proportion could be higher if the species introduced affected the most commonly fished species, such as snapper, or lower if the species introduced would not affect any recreationally fished species. There could possibly be some positive impacts if the introduced species provided additional food sources for recreationally fished predator species, but we do not model any in this CBA.

How severely this 38% of recreational fishing might be affected would also depend on which species was introduced. In the absence of information on how much each of the 14 introduced species modelled would affect the quality of the marine environment used for recreational fishing, we again adopt the 7% average impact on aquaculture production as broadly indicative. This 7% includes the likely responses of affected sectors as they change their behaviour to mitigate the impacts to which they are exposed. In this case, for example, some fishers might switch to less affected locations, seasons or fish species or increase fishing effort by fishing for longer to catch the same number of fish as previously.

As for marine tourism and recreation expenditure above, there is the added complication of how much a reduction in the quality of the marine environment used for recreational fishing would reduce the quality of the experience and enjoyment derived from fishing in this environment. How much would the need to clear additional biofouling from fishing lines, nets and cages and the reduction in populations of recreationally fished species affect recreational fishers' enjoyment. Catching fish is not the only source of enjoyment on fishing trips and, for many fishers, catching 7% fewer fish, or having to fish for longer to catch the same number of fish as previously, might not significantly reduce their enjoyment. For the purpose of the CBA, we again make the very simple assumption that, of the 7% reduction in quality of the recreational fishing environment, only around one fifth would translate into a loss in enjoyment and therefore loss in the value of recreational fishing. This could represent, for example, of every five fishers who suffer this 7% reduction in quality of the recreational fishing environment, one suffers an equivalent 7% reduction in enjoyment derived from this recreational fishing, or, alternatively, two suffer half as much reduction in enjoyment, 3.5%, or four suffer a quarter as much reduction in enjoyment, 1.75%, due to the impacts of the introduced species.

The combination of the above assumptions suggests that, by the time an introduced species completed its spread around New Zealand, it could be reducing the total national consumer surplus from recreational fishing by, on average, around $2.2 million per year (one fifth of 7% of 38% of $419 million). This should be treated as indicative only, given that estimates of the non-market value of recreational fishing span a wide range (Kerr and Latham, 2011). We consider the effect of smaller or larger impacts in the sensitivity analysis of Section 3.4 below. To model its gradual spread around New Zealand's coastline, we again adopt the weighted average of the spread of introduced species in New Zealand's coastal environment from Figure 9.

For each one less species introduced in a given year, recreational fishers would avoid the impact of this species on the value of recreational fishing in all subsequent years, as it would have gradually spread around New Zealand, and would do so for each one less species introduced in each additional year of the proposed IHS or voluntary standard. The impacts avoided are therefore additive with each additional species introduction avoided with each additional year. To derive the difference in total impacts avoided between the proposed IHS and the baseline scenario's voluntary standard, we apply the reduction in introduction rates of Table 14 above to the average impact per species over subsequent years, to model how much smaller the total impacts would be (i.e. how much would be avoided) in each year under the proposed IHS than under the voluntary standard.

2.7.9 Impacts on recreational shellfish gathering

There are fewer previous studies available on the non-market value of recreational shellfish gathering. Nimmo Bell (2008) derives an estimate of the willingness-to-pay per household per year to avoid the loss of three recreationally gathered shellfish species for three years at the Pauatahanui Inlet north of Wellington due to an incursion of European shore crab. This willingness-to-pay should reflect the social and cultural value of shellfish gathering to Māori and other ethnic groups, to the extent that these ethnic groups were represented in the households surveyed.

Based on Nimmo Bell (2008), we adopt an average non-market value of $41 per household per year (updated to 2012 prices). Aggregating across the 3,372 households around the Pauatahanui Inlet and approximately 350 estuaries around New Zealand's coastline (Nimmo Bell, 2008), this implies a total national non-market value for recreational shellfish gathering – or, more accurately, for avoiding its loss – of around $48 million per year. This, of course, assumes that the Pauatahanui Inlet can be treated as representative of all estuaries and that the three shellfish species gathered at this inlet can be treated as representative of all gathered species. In reality, each estuary is unique to some degree and values may be affected by site specific factors, including the availability and proximity of substitute shellfish species or gathering locations. The value per estuary is also likely to be higher for the last few estuaries affected and if the loss of shellfish species is permanent.

Again based on how much of New Zealand's coastal environment could provide suitable habitat for each of the 14 introduced species we model, we assume that on average around 38% of recreational shellfish gathering might be affected by new species introduced by vessel biofouling, either directly by their presence (e.g. obstructing access or causing harm through contact) or through their impacts on populations of shellfish species gathered. This proportion could be higher if the species introduced affected the most commonly gathered shellfish species or lower if the species introduced would not affect shellfish. There could possibly be some positive impacts if the introduced species could also be harvested for personal consumption, but we do not model any in this CBA.

How severely this 38% of recreational shellfish gathering might be affected would depend on which species was introduced. In the absence of information on how much each of the 14 introduced species modelled might affect the marine environment used for recreational shellfish gathering, we again adopt the 7% average impact on aquaculture production as broadly indicative. Again, this 7% includes changes in behaviour to mitigate impacts, such as some shellfish gatherers switching to less affected locations, times or shellfish species or increasing fishing effort by looking for longer to gather the same number of shellfish as previously.

As for recreational fishing above, there is the added complication of how much a reduction in the quality of the marine environment used for shellfish gathering would reduce the quality of the experience and enjoyment derived from gathering shellfish in this environment. How much would the presence of introduced species and the reduction in populations of shellfish species gathered affect how much gatherers value this activity. For many gatherers, shellfish gathering is an activity of social and cultural value over and above just a means of obtaining food and, for some, gathering 7% fewer shellfish or having to look for longer to gather the same number of shellfish as previously might not significantly reduce how much they enjoy and value this activity. For the purpose of the CBA, we again make the very simple assumption that, of the 7% reduction in quality of the recreational shellfish gathering environment, only around one fifth would translate into a loss in enjoyment and therefore loss in value of recreational shellfish gathering.

The combination of the above assumptions suggests that, by the time an introduced species completed its spread around New Zealand, it could be reducing the total national non-market value from recreational shellfish gathering by, on average, around $0.3 million per year (one fifth of 7% of 38% of $48 million). This is an order of magnitude smaller than the potential impact on recreational fishing, reflecting the higher number of New Zealanders participating in recreational fishing and its higher average value per person. We consider the effect of smaller or larger impacts in the sensitivity analysis of Section 3.4 below. To model its gradual spread around New Zealand's coastline, we again adopt the weighted average of the spread of introduced species in New Zealand's coastal environment.

For each one less species introduced in a given year, gatherers would avoid the impact of this species on the value of recreational shellfish gathering in all subsequent years, as it would have gradually spread around New Zealand, and would do so for each one less species introduced in each additional year of the proposed IHS or voluntary standard. The impacts avoided are therefore additive with each additional species introduction avoided with each additional year. To derive the difference in total impacts avoided between the proposed IHS and the baseline scenario's voluntary standard, we apply the reduction in introduction rates of Table 14 above to the average impact per species over subsequent years, to model how much smaller the total impacts would be (i.e. how much would be avoided) in each year under the proposed IHS than under the voluntary standard.

2.7.10 Impacts on recreational use of beaches

The most popular marine tourism and recreation activity reported is visiting beaches (Ministry of Tourism, 2009, and Statistics New Zealand, 2006). Over half of beach visitors walk and/or swim, many say they "just relax" and around one in 10 surf or kayak (Taranaki Regional Council, 2008). In many cases, the only cost of visiting a beach is that of travelling there, including travel time. In some cases, depending on what forms of beach recreation visitors participate in, there may be some costs for equipment, such as beach umbrellas, swimming costumes, surf boards, kayaks, etc., but this equipment is generally used many times once purchased. Especially for local residents, the cost of visiting a beach represents only a small fraction of how much visitors value this activity.

There have not been many studies undertaken in New Zealand of the non-market value of beaches, beyond to derive willingness-to-pay to protect beaches from erosion (Environment Waikato, 2006). This has been an active area of research overseas, however, especially in California and Florida. Based on the international literature, we adopt an average consumer surplus of $50 per person per visit (National Ocean Economic Program, 2006, Pendleton *et al.*, 2006, converted to New Zealand dollars and updated to 2012 prices). As noted above, consumer surplus represents the surplus of willingness-to-pay over the financial cost visitors actually pay, so ensures that we are not double counting any expenditure included in Section 2.7.7 above.

We adopt a mid-range estimate of the total national number of beach visits in New Zealand of 15 million per year. Using the numbers of reported beach visits by international and domestic tourists (Ministry of Tourism, 2009) and assuming that local residents make at least three times as many visits per year as domestic tourists suggests a total of over 10 million per year. In California, 51% of the population visits the beach once or more per year and 36% visits more than once a month (The Public Policy Institute of California, 2003). Applied to the population of New Zealand, these rates suggest a total of at least 20 million beach visits per year.

15 million beach visits per year at $50 each indicates a total national consumer surplus for beach recreation of around $750 million per year. This is around 1.8 times that of recreational fishing, which is not surprising given New Zealand's beach culture and that around 65% of the population lives within five kilometres of the coast (Statistics New Zealand, 2007).

As for recreational fishing and shellfish gathering, for the purpose of the CBA, we assume that on average around 38% of beach recreation might be affected by new species introduced by vessel biofouling, either directly by their presence or through their impacts on other species or, ultimately, on ecosystems and thereby the physical and aesthetic characteristics of the seashore. This proportion could be higher if the species introduced affected popular coastline close to major population centres or lower if the species introduced would not affect recreational use of the coastline. There could possibly even be some positive impacts, although we do not include any in this CBA. For example, *Carcinus maenas*, which likes rocky sheltered foreshore, could be a nuisance to some visitors, but an added attraction to others.

How severely this 38% of beach recreation might be affected would also depend on which species was introduced. In the absence of information on how much each of the 14 introduced species modelled might affect the quality of beaches for recreation, we adopt half the rate used for recreational fishing and shellfish gathering, an average of 3.5%, to reflect that some forms of beach recreation do not enter the water so would be less vulnerable to impacts from species introduced as vessel biofouling. This again includes changes in behaviour to mitigate impacts, such as some visitors switching to less affected beaches or less affected forms of beach recreation.

As for recreational fishing and shellfish gathering above, there is the added complication of how much a reduction in the quality of beaches for recreation would reduce the quality of the experience and enjoyment derived from visiting them. How much would the presence of introduced species and their impacts on populations of other species, ecosystems and the physical and aesthetic characteristics of the seashore affect visitors' enjoyment. For many visitors, a 3.5% reduction in the quality of beaches for recreation, might not significantly reduce how much they enjoy visiting it. For the purpose of the CBA, we again make the very simple assumption that, of the 3.5% reduction in quality of beaches for recreation, only around one fifth would translate into a loss in enjoyment and therefore loss in value from visiting the beach.

The combination of the above assumptions suggests that, by the time an introduced species completed its spread around New Zealand, it could be reducing the total national consumer surplus from beach recreation by, on average, around $2.0 million per year (one fifth of 3.5% of 38% of $750 million). This is slightly smaller than the potential impact on recreational fishing, which has fewer participants but would be likely to be more severely affected by introduced species, depending on which species was introduced. We consider the effect of smaller or larger impacts in the sensitivity analysis of Section 3.4 below. To model its gradual spread around New Zealand's coastline, we again adopt the weighted average of the spread of introduced species in New Zealand's coastal environment.

For each one less species introduced in a given year, beach visitors would avoid the impact of this species on the value of beach recreation in all subsequent years, as it would have gradually spread around New Zealand, and would do so for each one less species introduced in each additional year of the proposed IHS or voluntary standard. The impacts avoided are therefore additive with each additional species introduction avoided with each additional year. To derive the difference in total impacts avoided between the proposed IHS and the baseline scenario's voluntary standard, we apply the reduction in introduction rates of Table 14 above to the average impact per species over subsequent years, to model how much smaller the total impacts would be (i.e. how much would be avoided) in each year under the proposed IHS than under the voluntary standard.

2.7.11 Impacts on human health

A number of the types of species that could be introduced as biofouling on vessels have potential to affect human health.

In aquaculture, injuries can occur in cleaning shellfish of sea squirts or in pulling on lines made heavier by sea squirts and other biofouling. Workers can also suffer respiratory problems from use of caustic or harmful products to remove biofouling, if ventilation is inadequate. Contact with stinging sea anemones, such as in cleaning mussel buoys, can cause severe reactions. MPI's risk analysis finds the introduction of non-indigenous stinging sea anemones uncommon, however, so considers increased human health concerns unlikely (Ministry of Agriculture and Forestry, 2011). Some introduced crab species can be more aggressive than indigenous species and may be a nuisance to recreational fishers and other beach users. Nips to fingers and toes, although irritating, often do not cause more than a bruise, depending on species, but could result in more severe impacts if skin is lacerated and becomes infected. Of potential to affect more people, more severely, are outbreaks of shellfish poisoning from toxic algal blooms. Such events can also be caused by indigenous species, as well as non-indigenous species already established in New Zealand, and it can be difficult to determine which is the cause (Ministry of Agriculture and Forestry, 2011).

If new species that can affect human health were introduced, many of the above impacts could, however, be avoided or reduced. In aquaculture and commercial fishing, impacts on workers could be avoided by wearing protective equipment, which most operators already possess, and adhering to safe work practices. Aquaculture farms already have stringent procedures in place to prevent shellfish contamination and, if affected by a toxic algal bloom, would not sell shellfish that was not safe to eat. Following detection of a toxic algal bloom, recreational shellfish gathering areas at risk could be closed and access to beaches suspended. Beach users may also switch to different locations, times or activities to avoid the impacts of introduced species. Such responses would have some costs in terms of production impacts in aquaculture and losses in value derived from recreational fishing, recreational shellfish gathering and recreational use of beaches, but these are already modelled as part of this CBA.

2.7.12 Impacts on indigenous biodiversity

Marine biodiversity and ecosystem services

The term "biodiversity" can have many interpretations, but is most often defined as the total genes, species and ecosystems in a region. This implies three components – genetic diversity, species diversity and ecosystem diversity.

The services provided by ecosystems include (Millennium Ecosystem Assessment, 2003):

- provisioning services – products obtained from ecosystems:
  - food
  - fresh water
  - fuelwood
  - fibre
  - biochemical
  - genetic resources
- regulating services – benefits obtained from regulation of ecosystem processes:
  - climate regulation
  - disease regulation
  - water quality
  - water purification
  - pollination
- cultural services – non-material benefits obtained from ecosystems:
  - spiritual and religious
  - recreation and ecotourism
  - aesthetic
  - inspirational
  - educational
  - sense of place
  - cultural heritage
- supporting services – services necessary for the production of all other ecosystem services:
  - soil formation
  - nutrient cycling
  - primary production.

As much as 80% of New Zealand's plant and animal species occur in the marine environment and 44% of these species are not found anywhere else in the world (Ministry for the Environment, 2007). Little is known about many of these species.

The annual value of all services provided by New Zealand's marine ecosystems has been estimated at $184 billion (in 1994, Patterson and Cole, 1999).

New Zealand's indigenous biodiversity underpins the provision of all these ecosystem services. Any negative impacts had by introduced species on indigenous biodiversity could therefore impinge on the provision of these services. Potential impacts on indigenous biodiversity, although difficult to isolate, are therefore potentially large and could have wideranging consequences.

Impacts on indigenous biodiversity

Society may value avoiding adverse impacts on indigenous biodiversity at more than just the value derived from its current uses. Society may also value protecting indigenous biodiversity for possible use in future years (option value) or by future generations (bequest value), as well as on its continued existence independent of its current or possible future use (existence value).

In assessing the non-market values associated with an incursion of European shore crab at the Pauatahanui Inlet, Nimmo Bell (2008) also derives an estimate of willingness-to-pay per household per year to avoid a reduction in indigenous biodiversity, represented by loss of three indigenous shellfish species. This willingness-to-pay should reflect the social and cultural value of indigenous biodiversity to Māori and other ethnic groups, to the extent that these ethnic groups were represented in the households surveyed.

Based on Nimmo Bell (2008), we adopt an average non-market value of $64 per household per year (updated to 2012 prices). Aggregating across the 3,372 households around the Pauatahanui Inlet and approximately 350 estuaries around New Zealand's coastline (Nimmo Bell, 2008), this implies a total national non-market value for indigenous biodiversity – or more accurately, for avoiding a reduction in indigenous biodiversity – of around $76 million per year. Again, this assumes that the Pauatahanui Inlet and its indigenous biodiversity can be treated as representative of all estuaries. Although this is limited to estuaries and does not include all marine biodiversity, estuaries are arguably amongst the most vulnerable areas and where impacts are most visible to society.

Again based on how much of New Zealand's coastal environment could provide suitable habitat for each of the 14 introduced species we model as representative of the types of new species that could be introduced by vessel biofouling, for the purpose of this CBA we assume that on average around 38% of indigenous biodiversity could be affected by new species introduced as biofouling on vessels, in terms of the size and/or diversity of populations of indigenous species. This is quite uncertain and could be higher if the species introduced affected areas of particular importance or vulnerability for indigenous biodiversity or lower if the species introduced would not affect any indigenous species. There could possibly even be some positive impacts in providing additional habitats and food sources for some indigenous species, although we do not include any in this CBA.

How severely this indigenous biodiversity might be affected would also depend on the species introduced, as well as the species affected (e.g. if the species affected is abundant or already endangered). In the absence of information on how much each of the 14 introduced species modelled might affect the size and/or diversity of populations of indigenous species, we adopt an average of 10% as broadly indicative, given that the 7% average impact on aquaculture production adopted for marine tourism and recreation expenditure, recreational fishing, recreational shellfish gathering and beach recreation includes some mitigation of impacts by affected sectors.

As for these other affected sectors, there is the added complication of how much a reduction in the size and/or diversity of populations of indigenous species might reduce the value to society of indigenous biodiversity, especially where impacts on indigenous biodiversity are poorly understood, remote from most of society or even pertain to species that are considered a nuisance. How much would the presence of introduced species and their impacts on the size and/or diversity of populations of indigenous species affect the value to New Zealanders of indigenous biodiversity. For some households, a 10% reduction in the size and/or diversity of populations of indigenous species might not cause an equivalent loss in the value they place on New Zealand's indigenous biodiversity or, more accurately, how much they value avoiding this reduction in indigenous biodiversity. This would, of course, depend on which indigenous species were affected. For example, a 10% reduction in the size and/or diversity of the population of an indigenous species that is abundant or even considered a nuisance would not cause as large a loss in value as a 10% reduction in the size and/or diversity of the population of an indigenous species that is already endangered or considered a national icon. For the purpose of the CBA, we again make the very simple assumption that, of the 10% reduction in size and/or diversity of populations of indigenous species, on average around one fifth would translate into a loss in the value of this indigenous biodiversity to households.

The combination of the above assumptions suggests that, by the time an introduced species completed its spread around New Zealand, it could be reducing the total national non-market value of indigenous biodiversity by, on average, around $0.6 million per year (one fifth of 10% of 38% of $76 million). This estimate should be treated with caution. For the purpose of including in the CBA at least some representation of this potential impact of introduced species, we have adopted a very simplistic approach to modelling what is a very complex concept. This estimate does at least seem reasonable relative to others in the CBA. It is less than the potential impact on the value of recreational fishing but more than the potential impact on the value of recreational shellfish gathering and around 30% of the potential impact on the value of beach recreation. We consider the effect of smaller or larger impacts in the sensitivity analysis of Section 3.4 below. To model its gradual spread around New Zealand's coastline, we again adopt the weighted average of the spread of the 14 introduced species in New Zealand's coastal environment from Figure 9.

For each one less species introduced in a given year, society would avoid the impact of this species on the value of indigenous biodiversity in all subsequent years, as it would have gradually spread around New Zealand, and would do so for each one less species introduced in each additional year of the proposed IHS or voluntary standard. Again, the avoided impacts are additive with each additional species introduction avoided with each additional year. To derive the difference in total impacts avoided between the proposed IHS and the baseline scenario's voluntary standard, we again apply the reduction in introduction rates of Table 14 above to the average impact per species over subsequent years, to model how much smaller the total impacts would be (i.e. how much would be avoided) in each year under the proposed IHS than under the voluntary standard.

2.7.13 Summary of avoided impacts

Table 26 summarises the impacts avoided by reducing the number of species introduced by vessel biofouling. It shows the ongoing average annual impacts on affected sectors that would otherwise have occurred, per species introduced, once it had completed its spread throughout New Zealand. These impacts would obviously depend on which species was introduced. Treating each of the 14 introduced species modelled as equally likely of introduction, the aquaculture sector would suffer the greatest impacts per year, if not avoided. It would also reach this level of impacts sooner due to the faster spread of introduced species in aquaculture than in other environments.

For completeness, Table 26 includes initial incursion response expenditure avoided, although this would otherwise have been incurred for only the first three years of each introduction.

We consider the effect of lower or higher impacts in the sensitivity analysis of Section 3.4 below.

Table 26 Average impacts per sector per year, per species introduced, when spread complete
$ million, in 2012 prices

Sector	Impacts	
Greenshell mussels[1]	40.7	78%
Pacific oysters[1]	2.7	5.1%
King salmon[1]	2.4	4.6%
All aquaculture[1]	45.8	87%
Snapper[2]	0.8	1.5%
Red cod[2]	0.004	0.0%
Paua[2]	0.3	0.6%
All commercial fishing[2]	1.1	2.1%
Coastal infrastructure	0.02	0.0%
Marine tourism and recreation	0.5	1.0%
Recreational fishing	2.2	4.2%
Recreational shellfish gathering	0.3	0.6%
Recreational use of beaches	2.0	3.8%
Indigenous biodiversity	0.6	1.1%
Total impacts	52.5	
Initial incursion response expenditure	0.4 per year for first three years only	

Notes: [1] average across the 14 introduced species modelled, including species that would not affect aquaculture (from Table
19), [2] average across the 14 introduced species modelled, including species that would not affect commercial fishing (from Table 23)

2.7.14 Improved vessel fuel efficiency

Although the objective of both the proposed IHS and the voluntary standard would be to reduce the rate of introduction of new species to New Zealand, improving the management of biofouling on vessels may also have the incidental benefit of improving vessel fuel efficiency.

Fuel can be a large component of vessel operating costs, as much as 50% to 60% (World Shipping Council, 2008), depending on a variety of factors including vessel type, size, design, performance and handling. Fuel costs can range from around $250,000 per year for small fishing vessels to over $250,000 per week for cruise vessels and from under $100,000 to over $1 million per week for freight vessels (Ministry for the Environment, 2005, World Shipping Council, 2008, Deep Sea News, 2010).

The cost of fuel, as well as charges for associated greenhouse gas emissions, already provides a strong incentive to consume it efficiently. Since 2009, when the global economic downturn caused international trade and the demand for containerised shipping to plummet, this incentive has intensified as shipping companies have sought to maintain their financial viability. For example, by 2011, more than half of all global container shipping had adopted “slow steaming” at speeds of 18 to 20 knots or 33.3 to 37.0 kilometres per hour (Notteboom and Carriou, 2009, Vidal, 2010), although these slower speeds and longer travel times can exacerbate biofouling risks. In addition, the International Maritime Organization’s 2011 amendments to the International Convention for the Prevention of Pollution from Ships (International Maritime Organization, 2011c) make energy efficiency management plans mandatory for all vessels, which can be expected to reinforce the need to consume fuel efficiently.

Through increasing frictional resistance, biofouling can reduce the fuel efficiency of vessels by up to 20% (Schultz *et al*., 2011). Biofouling of niche areas, such as propellers and propeller shafts, can increase fuel consumption by up to 10% (Anderson *et al*., 2003, Wilson, 1999). Even for small vessels, regular hull maintenance, including removal of biofouling, can improve fuel efficiency by around 7% (Ministry for the Environment, 2005) and modern antifouling coatings can provide fuel savings of around 6% (Seafood Industry Council and Energy Efficiency and Conservation Authority, 2010).

Commercial vessels already manage biofouling to some extent for safety and materials protection, as well as fuel efficiency. Given the cost of fuel, most commercial vessels already manage any biofouling that would significantly impede their fuel efficiency.

There may, however, be some further fuel savings available that vessels do not consider worth securing currently, but would be achieved as a consequence of improving biofouling management to comply with the proposed IHS or the baseline scenario’s voluntary standard. Under perfect information and economically rational behaviour, we could expect vessels currently to be managing biofouling that affects their fuel efficiency up to the point where the value of the additional fuel savings achieved just covers the costs of the incremental improvement in biofouling management (i.e. where marginal benefit equals marginal cost). Beyond this point, further improvements in biofouling management would cost more than the fuel savings they would achieve.

Under the proposed IHS or voluntary standard, some vessels improving their biofouling management to comply with this standard may incidentally also achieve these additional fuel savings, even though these were not the reason for improving biofouling management and may be less than the additional costs of achieving them (otherwise economically rational vessels would be securing them already). The additional fuel savings for these vessels would be an additional, albeit incidental and relatively minor, benefit of improving biofouling management to comply with the proposed IHS or voluntary standard. Although small relative to other benefits, we include this additional benefit in this CBA for completeness.

MPI advises that information from its vessel biofouling research programme indicates that around a quarter of non-compliant commercial vessels could achieve improved fuel efficiency with improved biofouling management of their hull and niche areas. We therefore model 25% of commercial vessels that improve their biofouling management to comply with the proposed IHS or voluntary standard also incidentally achieving additional fuel savings.

We do not know how deficient the existing biofouling management of these vessels is with regard to maximising fuel efficiency. Under perfect information, the economically rational level discussed above – where the costs of further improvements in biofouling management would exceed the value of the additional fuel savings that achieved – would be a reasonable assumption. In reality, vessels do not have perfect information on the relationship between biofouling management and fuel efficiency. At the time of cleaning and antifouling, there is significant uncertainty as to precisely how much difference better treatment would make to fuel consumption over subsequent years. To allow for some sub-optimality in current biofouling management for fuel efficiency, we assume that, on average, twice the economically rational level of fuel savings are not secured currently but would be in improving biofouling management to comply with the proposed IHS or voluntary standard.

We therefore model 25% of commercial vessels becoming compliant with the proposed IHS or voluntary standard also achieving ongoing average fuel savings per year of twice the average cost per year of improving their biofouling management to comply with the proposed IHS or voluntary standard (i.e. twice the compliance costs of Table 7 above). Table 27 shows these ongoing average additional fuel savings per vessel per year, by vessel type. We consider the effect of lower or higher fuel efficiency benefits per vessel in the sensitivity analysis of Section 3.4 below.

Table 27 Average fuel efficiency benefits per vessel per year
$, in 2012 prices

Vessel Type	Fuel savings
Container	27,050
Bulk	21,676
General cargo	21,100
Tanker	29,063
Other commercial	31,875
Cruise	41,500
Fishing	35,350

2.8 Timeframe

2.8.1 Timeframe

There are generally four options in setting the timeframe covered by a CBA:

- the duration of the proposal – this is not suitable where a large proportion of the impacts of the proposal would occur after its completion
- the planning or budgeting horizon of the decision-maker – for public sector investments, this can range from 10 to 50 years and is generally around 25 to 35 years, but a short planning horizon should not constrain the CBA unless the decision-maker explicitly requires the proposal to pay off within this period
- the length of time taken for impacts to reach a steady state (equilibrium) – this is commonly used in economic impact assessments of biosecurity incursions, reflecting how long it would take for an unwanted organism to complete its spread and therefore to reach the level of annual impacts it would have on affected sectors ongoing or
- in perpetuity – if the options or scenarios modelled differ significantly ongoing.

The timeframe adopted needs to be long enough to capture all major impacts or differences in impacts between options or scenarios, such that extending the timeframe would not alter the CBA's findings on whether the proposal is worthwhile or which option is preferable. We would not normally adopt timeframes longer than 25 to 35 years, however, given greater uncertainty about future developments in technological, economic, social and even environmental conditions beyond this time, as well as the pronounced effect of discounting on impacts occurring beyond this time.

Adopting a 10 or 20 year timeframe in this CBA, in expectation that the IHS, in the form currently proposed, would not remain forever, would not capture sufficient benefits to provide a robust assessment, given the rates of spread of the 14 species we model as representative of the types of species that could be introduced as biofouling on vessels. Furthermore, MPI advises that although the proposed IHS may not remain forever, vessel biofouling could be expected to continue to pose a risk to New Zealand's biosecurity for the foreseeable future, such that even if the IHS proposed currently ended, it would be likely to be followed by another standard, whether mandatory or voluntary, or some other form of intervention to manage this risk. We do not yet know what the successor to the proposed IHS might be or even whether it would be less or more stringent. It therefore seems reasonable to model the proposed IHS remaining indefinitely until an explicit decision is made to amend or replace it.

Adopting a timeframe of 100 years or more, to reflect that reducing the number of species introduced in a given year would provide ongoing benefits in perpetuity, would stretch the limits of certainty about future developments in technological, economic, social and even environmental conditions, but also most of the years in this timeframe would make relatively little difference to present value total benefits due to the more pronounced effect of discounting on more distant future benefits (discounting is explained in Section 2.8.2 below and its effect on the CBA results over different timeframes is explored in Section 3.2).

In balancing these two considerations, we adopt a timeframe of 50 years for this CBA, but also compare total costs and benefits over shorter timeframes of 10, 20, 30 and 40 years. Only one of the 14 introduced species modelled would take more than 50 years to complete its spread. Both the proposed IHS and the voluntary standard would incur costs from the start to achieve benefits into the future, through improving biofouling management to reduce the rate of introduction of new species. Adopting a 50 year timeframe does not capture all of the benefits, which would continue in perpetuity, but captures enough of the benefits to provide robust and conclusive findings on whether the proposed IHS would deliver greater net benefits than the baseline scenario's voluntary standard.

2.8.2 Discounting

We then discount all costs and benefits over this timeframe according to when they would occur, so that we can compare directly costs and benefits occurring at different points in time. This reflects that society values a dollar of cost or benefit occurring at some point in the future less than a dollar occurring today, according to how soon or distant it is. Discounting converts all future costs and benefits to their "present value", in this case in 2012.

The choice of discount rate is subject to considerable debate and may be influenced by the scope and perspective of a CBA given that the opportunity cost of capital and the rate of time preference may vary according to context. Historically, private sector investments have tended to be subject to market discount rates of 10% to 12%. For public sector investments, a number of overseas governments and international organisations have recommended discount rates of 6% to 10%, although the United Kingdom recently revised its discount rate down from 6% to 3.5% in unbundling "optimism bias" (the tendency to be overly optimistic in the initial assessment of a proposal's costs, benefits and timelines) from the discount rate (Her Majesty's Treasury, 2011). The behaviour of individuals has been observed to be consistent with discount rates in the range of 5% to 7%.

In 2008, the New Zealand Treasury reduced its recommended discount rate for use in CBA from a national economy perspective from 10% to 8% (Treasury, 2008). Applying this rate consistently across all CBAs of proposed public expenditure also assists direct comparison for prioritisation purposes.

We therefore adopt a standard approach of applying the Treasury recommended discount rate of 8% and examining the sensitivity of the CBA results to higher or lower discount rates. In the sensitivity analysis of Section 3.4 below, we model discount rates of 12%, to reflect a commercial perspective, 6%, to reflect a public policy perspective, and 3.5%, to reflect the lower rate recently adopted by the United Kingdom.

Ultimately, the choice of discount rate is critical only where the net benefits of a proposal are marginal, which signals the need to reconsider the design and/or effectiveness of the proposal.

3 Results

3.1 Annual costs and benefits

Figure 10 and Figure 11 show the costs and benefits of the proposed IHS in each year, relative to the baseline scenario's voluntary standard, under the two international scenarios of voluntary or mandatory standards in Australia and California. Because these costs and benefits are measured relative to the baseline scenario, they represent the *additional* costs and benefits of the proposed IHS over those of the voluntary standard.

Figure 10 . Additional annual costs and benefits of proposed IHS – Scenario V (voluntary standards in Australia and California)
In 2012 prices, year to December

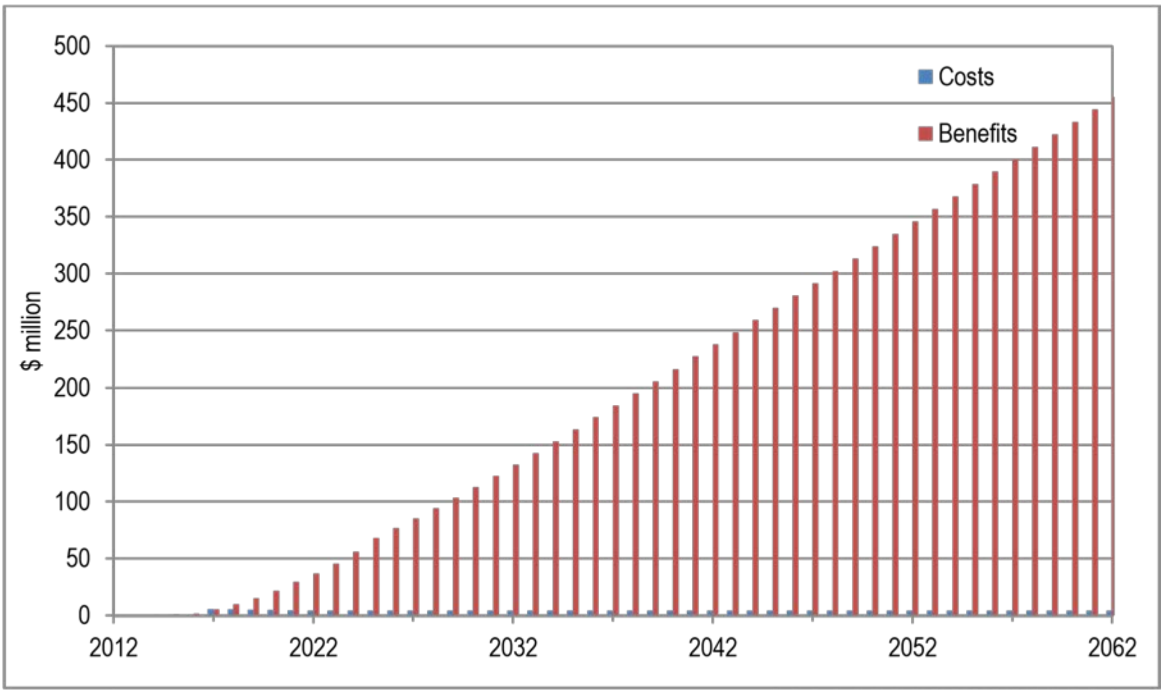
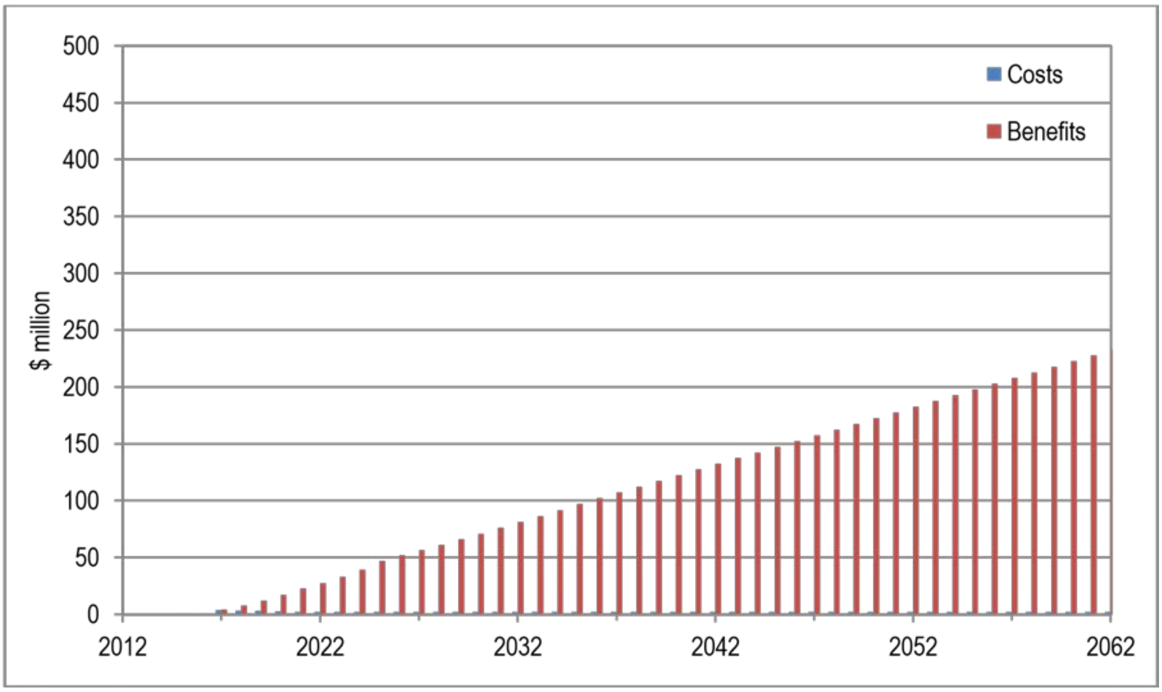


Figure 11 Additional annual costs and benefits of proposed IHS – Scenario M (mandatory standards in Australia and California)
In 2012 prices, year to December



Note that these costs and benefits do not include border process costs, which MPI considers unlikely to be significant or more than minor, and human health benefits, given that the other benefits modelled incorporate responses of affected sectors to avoid or reduce adverse impacts on human health.

The proposed IHS would have only slightly higher costs and benefits than the voluntary standard for the initial four year voluntary period. These slightly higher costs and benefits reflect the higher uptake of compliance in preparation for the proposed IHS becoming mandatory and the higher percentage of non-compliant recreational vessels directed to take action to mitigate their biofouling risks.

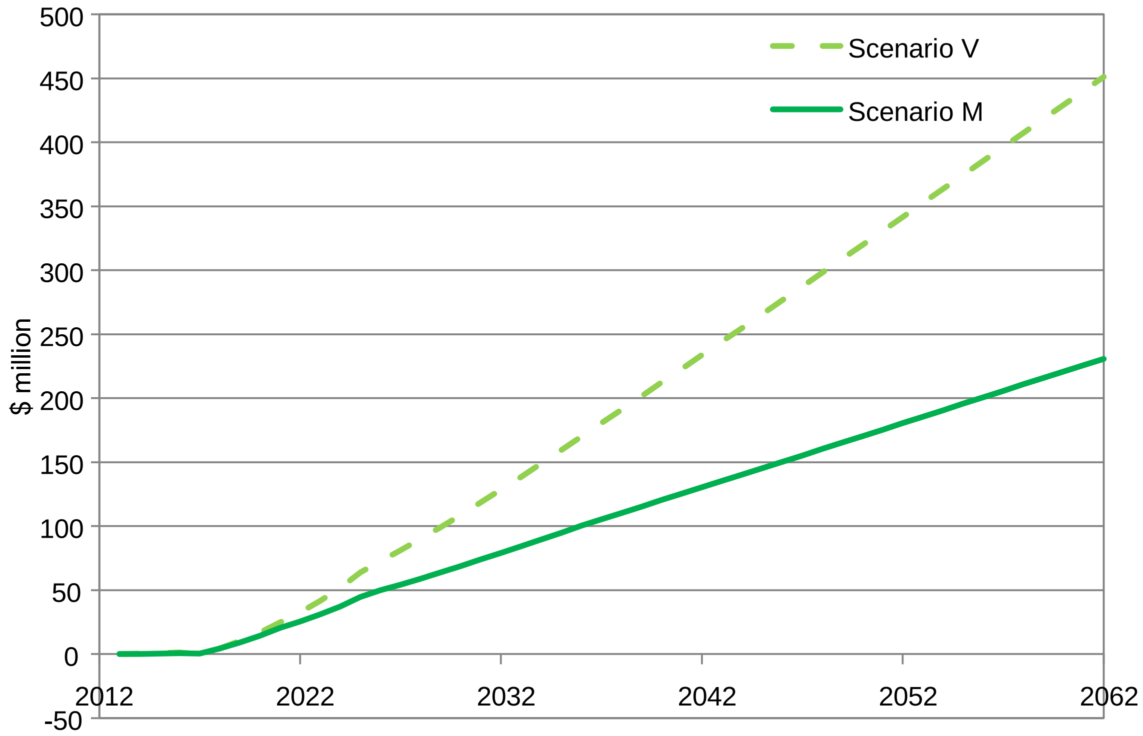
The additional costs of the proposed IHS relative to the voluntary standard would rise markedly in year 5 (2017) when the proposed IHS would become mandatory and percentages of non-compliant vessels of all types would be directed to take action to mitigate their biofouling risks. The additional costs of the proposed IHS would be highest in year 5, at around $5.5 million under voluntary standards in Australia and California and $3.7 million under mandatory standards in Australia and California. They would decline thereafter, as compliance rates rose and therefore fewer non-compliant vessels were directed to take action to mitigate their biofouling risks, until year 10 (2022) when compliance rates reached their upper limits. From year 10, under constant compliance rates, the additional costs of the proposed IHS would remain constant at around $4.2 million per year under voluntary standards in Australia and California and $2.1 million under mandatory standards in Australia and California.

In contrast, the additional benefits of the proposed IHS relative to the voluntary standard would start low and continue to rise over time. Reducing the number of new species introduced in a given year would provide benefits into the future in avoiding the impacts they would otherwise have had on affected sectors, which would have risen over time as the introduced species gradually spread. Lower introduction rates under the proposed IHS would therefore provide small additional benefits in the short run, but large additional benefits in the long run. The additional benefits of the proposed IHS would rise from around $0.1 million in the first year (2013) to as much as $455 million per year under voluntary standards in Australia and California and $233 million per year under mandatory standards in Australia and California in year 50 (2062).

Both the additional costs and the additional benefits of the proposed IHS would be higher in all years under voluntary than mandatory standards in Australia and California. These jurisdictions' standards would already result in some improvement in biofouling management and reduction in risk to New Zealand to the extent that vessels visiting these jurisdictions and already complying with their standards also visited New Zealand. This existing improvement in biofouling management would be less if these standards were only voluntary and therefore the additional improvement achieved by the proposed IHS would be greater.

Subtracting the additional costs of the proposed IHS in each year from the additional benefits indicates additional annual net benefits as shown in Figure 12 below. These additional net benefits would be positive in all but year 5 (2017) under voluntary standards in
Australia and California and in all years under voluntary standards in Australia and California. The additional net benefits of the proposed IHS would be higher in all years except years 5 and 6 (2017 and 2018) if Australia and California had voluntary standards than if they had mandatory standards. This is because the proposed IHS would achieve a greater additional improvement in biofouling management if Australia and California had only voluntary standards and thereby incur higher costs in all years, but deliver higher benefits in the longer run from lower rates of introduction of new species.

Figure 12 . Additional annual net benefits of proposed IHS
In 2012 prices, year to December



3.2 Total costs and benefits

With discounting to reflect their relative timing, the above annual costs and benefits imply present value total costs and benefits over the first 10, 20, 30 40 and 50 years of the proposed IHS, relative to the baseline scenario's voluntary standard, as shown in Figure 13 and Figure 14. Again, because these total costs and benefits are measured relative to the baseline scenario, they represent the *additional* total costs and benefits of the proposed IHS over those of the voluntary standard.

These total costs and benefits may seem low relative to the annual costs and benefits reported in Section 3.1 above, but this is due to the effect of discounting, which becomes more pronounced the further the annual costs and benefits lie into the future. For example, discounting at 8% would reduce a $1 million annual cost occurring in 10 years time to a present value today of $0.463 million, $1 million occurring in 30 years time to a present value today of $0.099 million and $1 million occurring in 50 years time to a present value today of just $0.021 million. Each additional year of this annual cost, when discounted, would therefore add less to the present value total costs.

Figure 13 Additional present value total costs and benefits of proposed IHS – Scenario V (voluntary standards in Australia and California)
In 2012 prices and present values

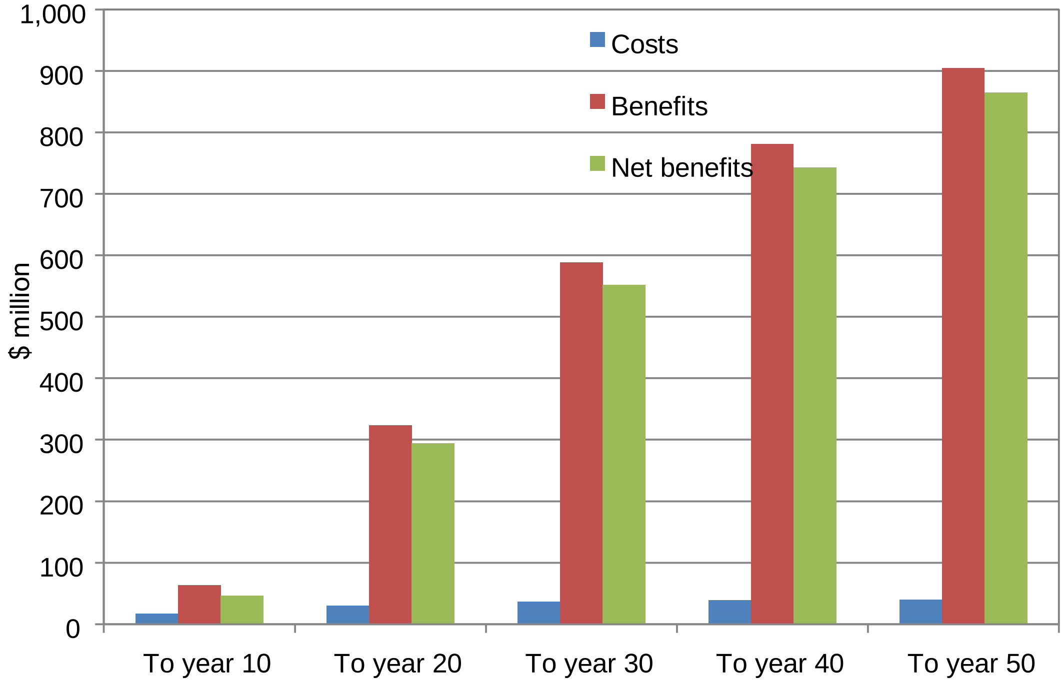
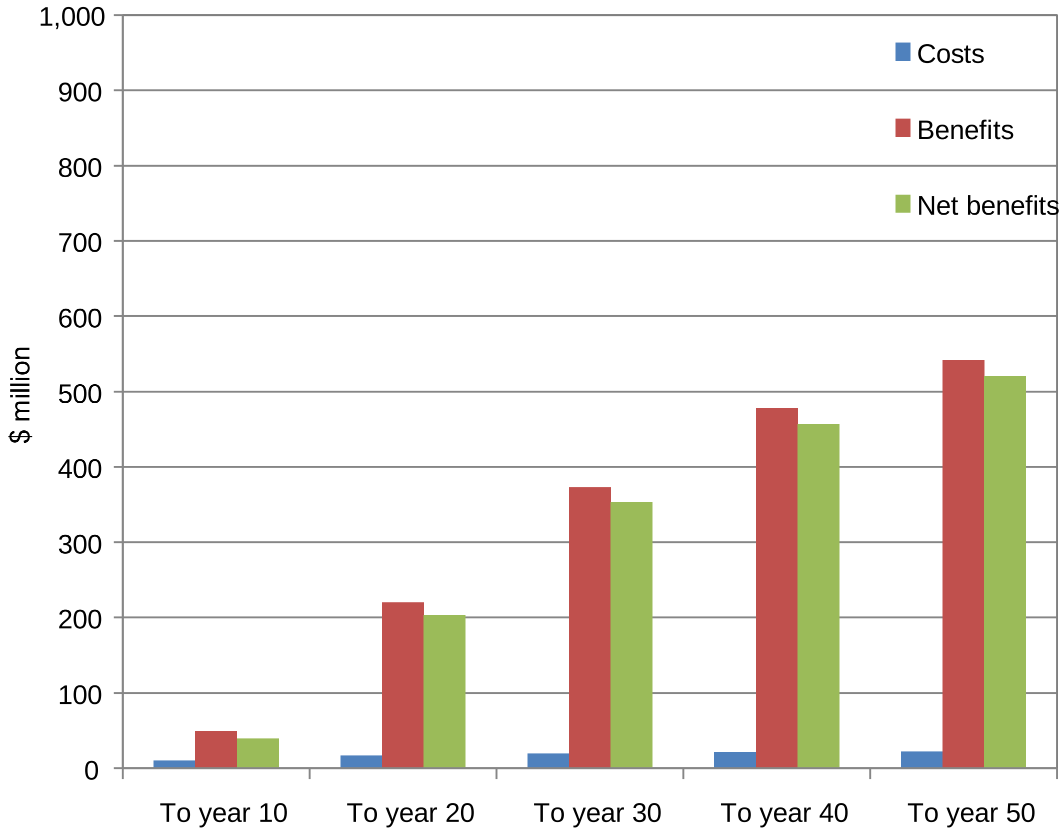


Figure 14 Additional present value total costs and benefits of proposed IHS – Scenario M (mandatory standards in Australia and California)
In 2012 prices and present values



Given the gradual spread of introduced species, lower introduction rates under the proposed IHS would provide small additional benefits in the short run, but large additional benefits in the long run. The results of this CBA suggest that, over all timeframes shown in Figure 13 and Figure 14, the additional benefits of the proposed IHS in avoiding the impacts of introduced species on affected sectors would be sufficient to outweigh the additional costs incurred in improving biofouling management. Even within the first 10 years, sufficient additional benefits would accrue to cover the additional costs accumulated over these years.

This is despite the discounting of future costs and benefits to their present values having a more pronounced effect the further these costs and benefits lie into the future. Due to the effect of discounting on constant annual costs, the total costs shown in Figure 13 and Figure 14 increase relatively little, and by less, with each decade added to the timeframe. In contrast, annual benefits increase so much over time that, despite the effect of discounting, the total benefits still increase substantially each additional decade. For example, under Scenario V, between year 30 and year 40 the present value total costs increase by $2.8 million and between year 40 and year 50 they increase by just $1.3 million. In comparison, between year 30 and year 40 the present value total benefits increase by $193.5 million and between year 40 and year 50 they increase by $123.3 million.

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Table 28 Additional present value total costs and benefits of proposed IHS
In 2012 prices and present values

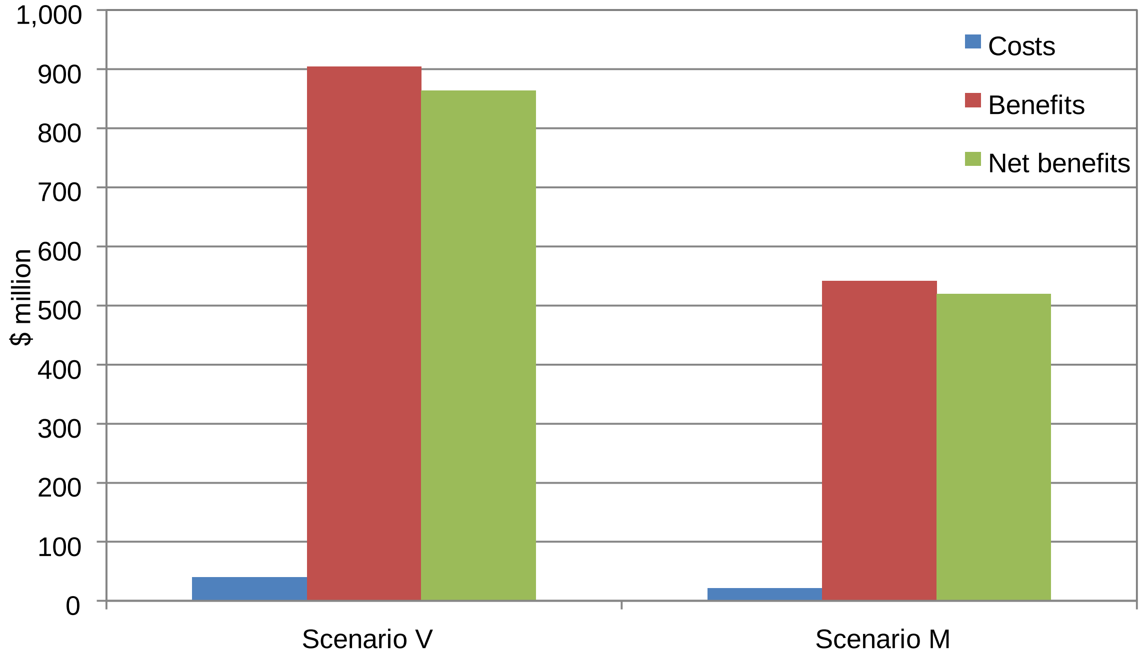
	To year 10	To year 20	To year 30	To year 40	To year 50
Scenario V (voluntary standards in Australia and California)					
Costs ($ million)	17.2	30.2	36.1	38.9	40.2
Benefits ($ million)	63.8	324.1	588.1	781.5	904.8
Net benefits ($ million)	46.6	293.9	551.9	742.6	864.6
Benefit-cost ratio	3.7	10.7	16.3	20.1	22.5
Scenario M (mandatory standards in Australia and California)					
Costs ($ million)	10.0	16.5	19.5	20.9	21.5
Benefits ($ million)	49.1	219.9	373.1	477.6	541.6
Net benefits ($ million)	39.1	203.4	353.6	456.7	520.1
Benefit-cost ratio	4.9	13.3	19.1	22.9	25.2

Over the 50 years 2013 to 2062 inclusive, the proposed IHS is estimated to deliver additional net benefits of between $520 million (Scenario M) and $865 million (Scenario V), in terms of present value in 2012. For each additional dollar of cost incurred, the proposed IHS is estimated to deliver around $23 to $25 in additional benefits by this time, even in terms of present value to reflect that there would be a delay between when each dollar of cost was incurred and when most of the resulting benefits would occur.

Indeed, benefits would continue to accrue beyond these 50 years. Even if the proposed IHS was ended and not replaced with another standard or any other form of intervention, it would continue to provide benefits long afterwards from the ongoing impacts avoided by introduction of fewer new species during its operation. We could model the benefits in perpetuity, but 50 years is already a long timeframe given possible changes in technology, economic conditions, social values, the marine environment and even the climate over this period, and, as Figure 13 and Figure 14 demonstrate, a 50 year timeframe is more than enough to demonstrate convincingly that the proposed IHS would provide substantially greater net benefits than the alternative of the voluntary standard.

Although the proposed IHS would incur higher additional costs if Australia and California had only voluntary standards (Scenario V), it would also deliver sufficiently higher additional benefits under this scenario to provide higher additional net benefits, although the ratio of benefits to costs would be slightly lower.

Figure 15 Additional present value total costs and benefits of proposed IHS to year 50
In 2012 prices and present values



3.3 Distribution of total costs and benefits

Table 29 shows the distribution of the present value total costs and benefits over the 50 years 2013 to 2062 by type.

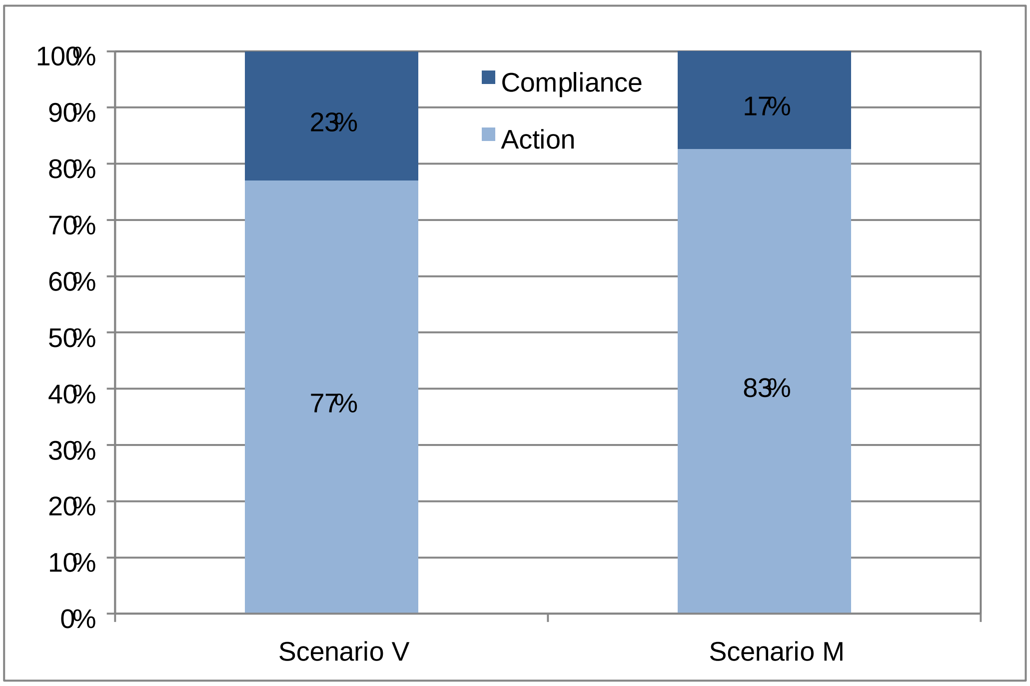
Table 29 Distribution of additional present value total costs and benefits of proposed IHS to year 50
$ million, in 2012 prices and present values

	Scenario V	Scenario M
Costs		
Compliance	9.2	3.7
Action	31.0	17.8
Total costs	40.2	21.5
Benefits	2.0	0.8
Initial incursion response		
Aquaculture	815.7	488.7
Commercial fishing	15.5	9.4

Coastal infrastructure	0.3	0.2
Marine tourism and recreation	5.7	3.5
Recreational fishing	26.9	16.3
Recreational shellfish gathering	3.1	1.9
Recreational use of beaches	24.1	14.6
Indigenous biodiversity	6.9	4.2
Vessel fuel efficiency	4.6	1.9
Total benefits	904.8	541.6
Total net benefits	**864.6**	**520.1**

The largest component (77% to 83%) of the estimated additional costs of the proposed IHS is the costs to non-compliant vessels directed to take action to mitigate their biofouling risks.

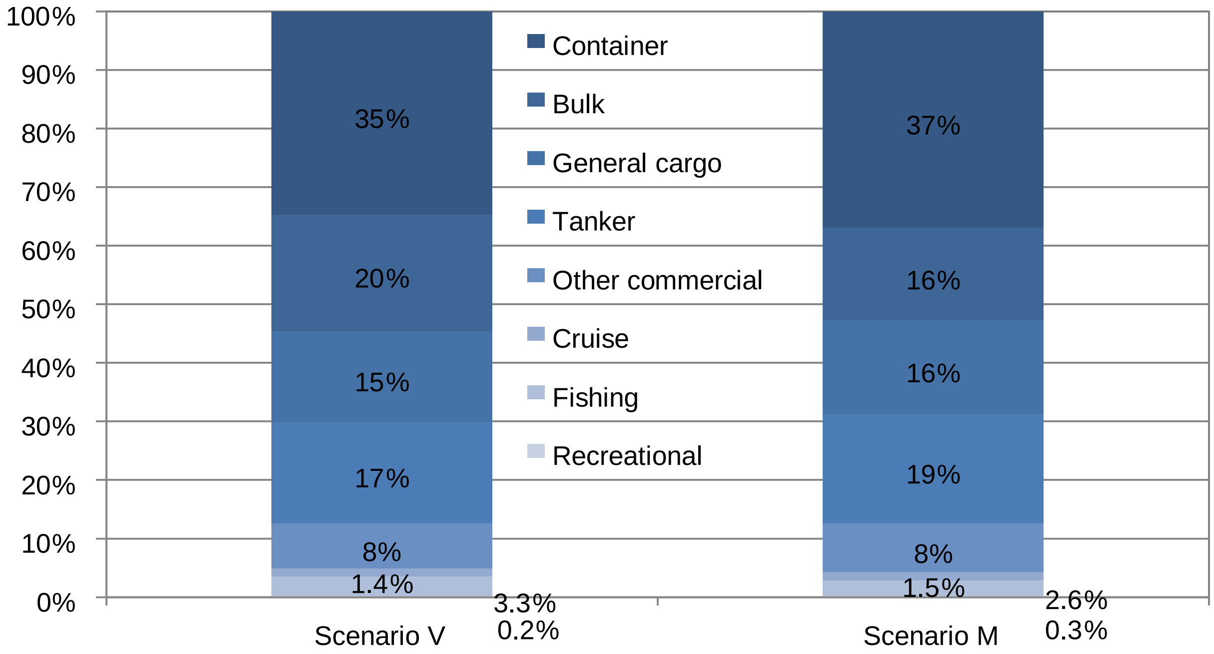
Figure 16 Distribution of additional present value total costs of proposed IHS to year 50 – by type of cost



Of the estimated additional costs, around 95% fall on freight vessels. This is partly because freight vessels account for three-quarters of vessel arrivals per year, but also because we model freight vessels as having by far the highest action costs per vessel, from the disruption to their ability to deliver and pick up freight if directed to leave New Zealand. Container vessels, in particular, account for 39% of all vessel arrivals per year. Although recreational vessels and fishing vessels are modelled as having higher action rates than freight vessels, they would have much lower action costs per vessel.

Up to 1.5% of the estimated additional costs to vessels fall on cruise vessels, up to 3.3% on fishing vessels and up to 0.3% on recreational vessels. Although cruise and fishing vessels face the highest compliance costs per vessel (after slow moving/specialist vessels, which we do not model), they face the lowest action costs per vessel after recreational vessels.

Figure 17 Distribution of additional present value total costs to vessels of proposed IHS to year 50 – by type of vessel



By far the largest component (90%) of the estimated additional benefits of the proposed IHS is the avoided impacts of introduced species on aquaculture, given its vulnerability to most of the species that could be introduced by vessel biofouling. This is followed by recreational fishing (3.0%) and recreational use of beaches (2.7%), given the popularity of these activities.

Figure 18 Distribution of additional present value total benefits of proposed IHS to year 50 – by type of impacts avoided

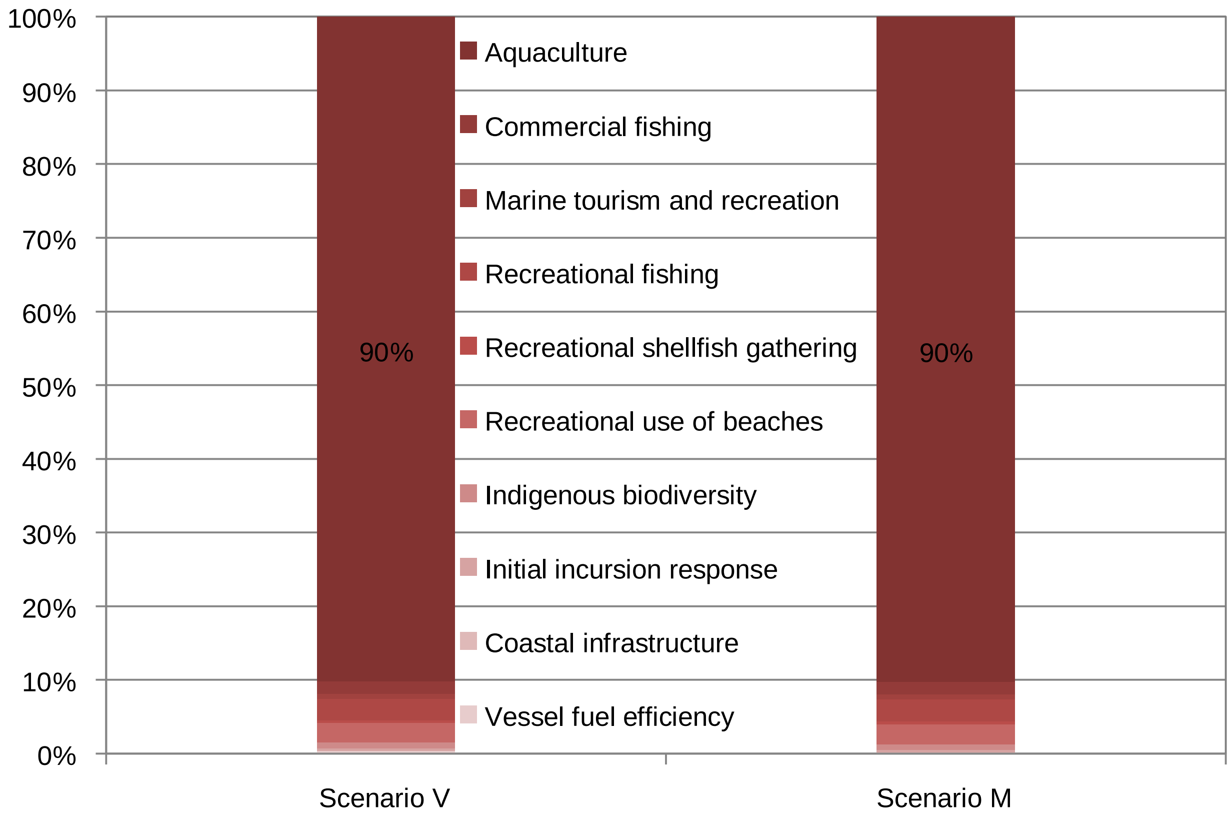


Figure 19 Distribution of additional present value total benefits of proposed IHS to year 50 – by type of impacts avoided, non-aquaculture

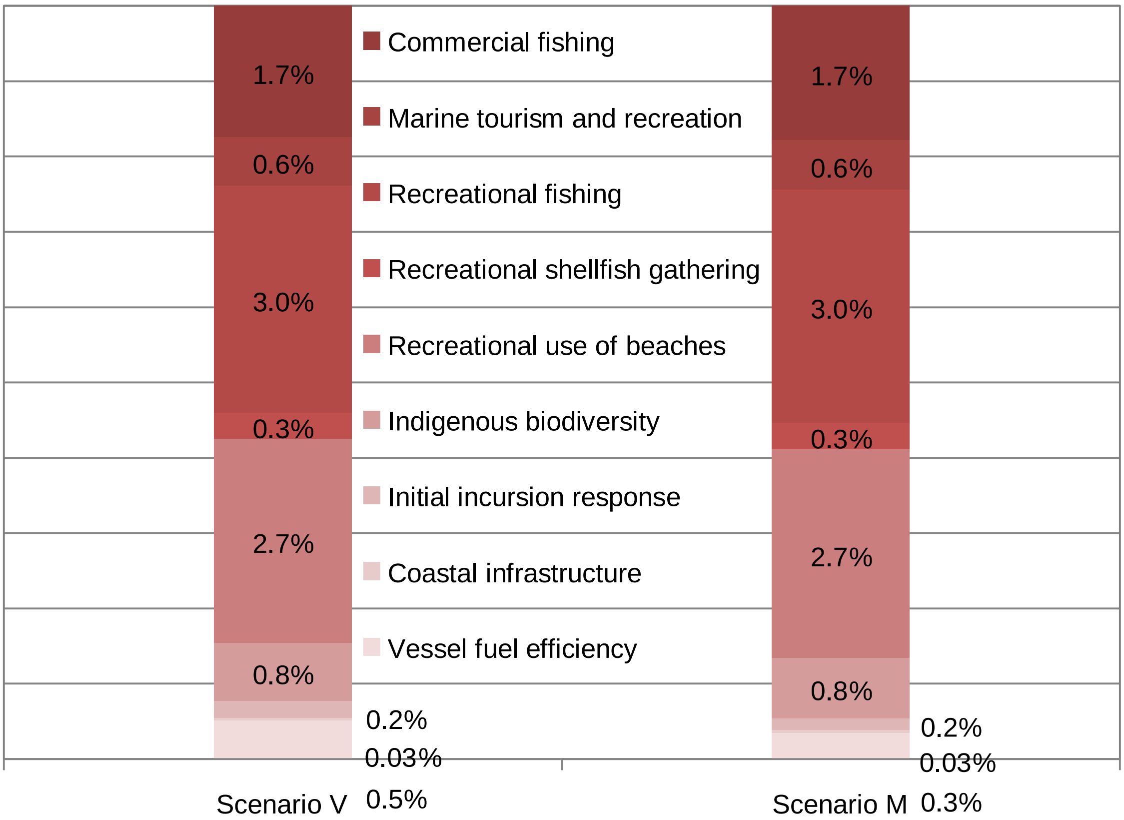


Figure 20 Distribution of additional present value total benefits of proposed IHS to year 50 – by aquaculture fishery

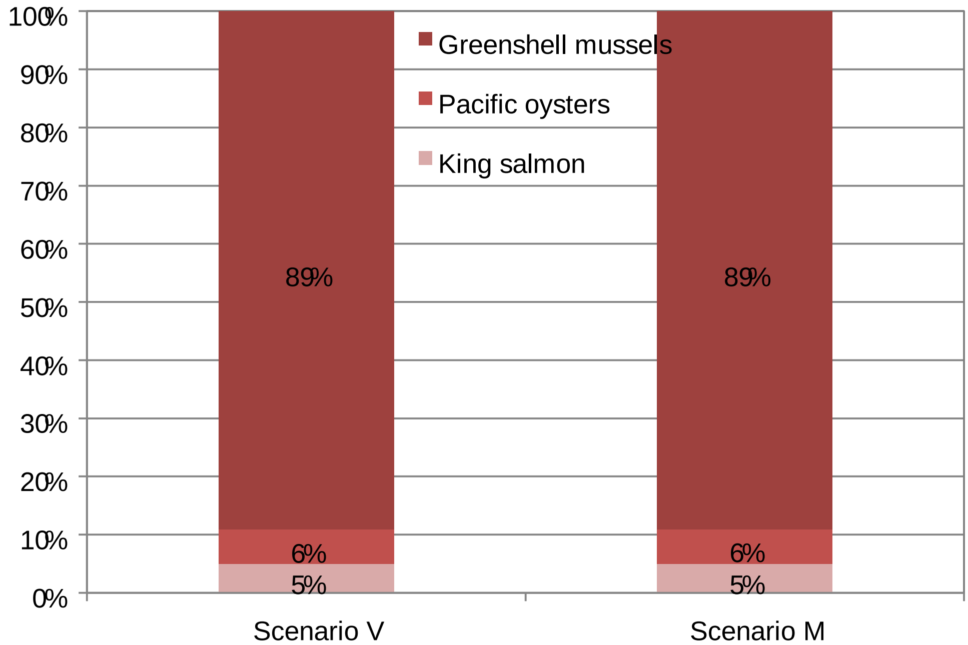
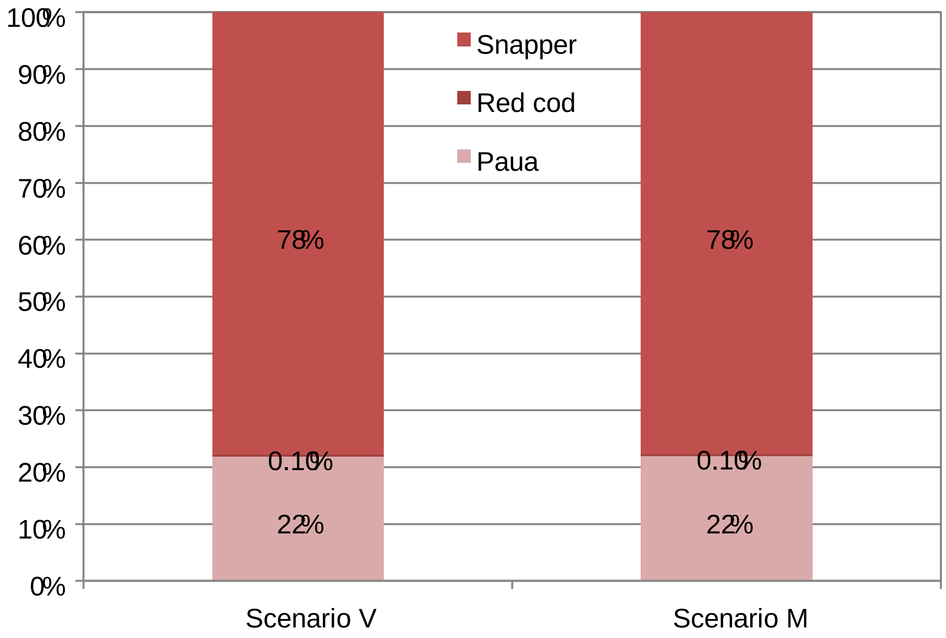


Figure 21 Distribution of additional present value total benefits of proposed IHS to year 50 – by commercial fishery



3.4 Sensitivity analysis

Given uncertainty about many of the inputs used in modelling the costs and benefits of the proposed IHS relative to the baseline scenario's voluntary standard, we test the sensitivity of the main results reported above across a range of values for the inputs into the CBA. We do this by exploring how adopting a 10% or 25% lower or higher value for each input, independently of other inputs, alters the estimated additional present value total net benefits of the proposed IHS over the 50 years 2013 to 2062, under each of the two international scenarios.

3.4.1 Costs

Of the two types of costs modelled in the CBA, the additional net benefits of the proposed IHS relative to the voluntary standard are most sensitive to the costs to non-compliant vessels directed to take action to mitigate their biofouling risks, more so for freight vessels than other vessel types.

Adopting 25% lower (or higher) action costs per vessel for freight vessels increases (decreases) the estimated additional net benefits of the proposed IHS by up to 0.9%, as shown in Table 31 below. Of least effect is adopting lower or higher action costs per vessel for cruise vessels.

Adopting 25% lower (higher) action costs per vessel for all vessel types increases (decreases) the estimated additional net benefits of the proposed IHS by 0.9%, to $872 million ($857 million) under Scenario V and $525 million ($516 million) under Scenario M.

Table 30 Change in additional net benefits of proposed IHS with adoption of lower or higher costs per vessel
Change in additional present value total net benefits of proposed IHS to year 50

Cost type	**Change in costs per vessel**			
	-25%	**-10%**	**+10%**	**+25%**
Scenario V (voluntary standards in Australia and California)				
Compliance	0.3%	0.1%	-0.1%	-0.3%
Action	0.9%	0.4%	-0.4%	-0.9%
Scenario M (mandatory standards in Australia and California)				
Compliance	0.2%	0.1%	-0.1%	-0.2%
Action	0.9%	0.3%	-0.3%	-0.9%

Table 31 Change in additional net benefits of proposed IHS with adoption of lower or higher action costs per vessel
Change in additional present value total net benefits of proposed IHS to year 50

Vessel type	Change in action costs per vessel			
	-25%	-10%	+10%	+25%
Scenario V (voluntary standards in Australia and California)				
Container	0.27%	0.11%	-0.11%	-0.27%
Bulk	0.34%	0.14%	-0.14%	-0.34%
General cargo	0.17%	0.07%	-0.07%	-0.17%
Tanker	0.16%	0.06%	-0.06%	-0.16%
Other commercial	0.15%	0.06%	-0.06%	-0.15%
All freight	0.9%	0.4%	-0.4%	-0.9%
Cruise	0.0006%	0.0002%	-0.0002%	-0.0006%
Fishing	0.011%	0.004%	-0.004%	-0.011%
Recreational	0.002%	0.001%	-0.001%	-0.002%
All vessel types	0.9%	0.4%	-0.4%	-0.9%
Scenario M (mandatory standards in Australia and California)				
Container	).18%	0.07%	-0.07%	-0.18%
Bulk	0.33%	0.13%	-0.13%	-0.33%
General cargo	0.15%	0.06%	-0.06%	-0.15%
Tanker	0.15%	0.06%	-0.06%	-0.15%
Other commercial	0.15%	0.06%	-0.06%	-0.15%
All freight	0.8%	0.3%	-0.3%	-0.8%
Cruise	0.0006%	0.0002%	-0.0002%	-0.0006%
Fishing	0.016%	0.006%	-0.006%	-0.016%
Recreational	0.003%	0.001%	-0.001%	-0.003%
All vessel types	0.9%	0.3%	-0.3%	-0.9%

3.4.2 Benefits

Of the benefits modelled in the CBA, the additional net benefits of the proposed IHS are most sensitive to the avoided impacts of introduced species on Greenshell mussels, followed by Pacific oysters, king salmon, recreational fishing and recreational use of beaches. The smaller the impacts of introduced species, the smaller the impacts avoided by the proposed IHS and therefore the benefits.

Adopting 25% smaller (greater) production impacts on Greenshell mussels decreases (increases) the estimated additional net benefits of the proposed IHS by 21%, as shown in Table 32.

Table 32 Change in additional net benefits of proposed IHS with adoption of lower or higher unit value of impacts avoided
Change in additional present value total net benefits of proposed IHS to year 50

Benefit Type	Change in unit benefits			
	-25%	-10%	+10%	+25%
Scenario V (voluntary standards in Australia and California)				
Initial incursion response	-0.06%	-0.02%	0.02%	0.06%
Greenshell mussels	-21.0%	-8.4%	8.4%	21.0%
Pacific oysters	-1.4%	-0.6%	0.6%	1.4%
King salmon	-1.2%	-0.5%	0.5%	1.2%
All aquaculture	-23.6%	-9.4%	9.4%	23.6%

Snapper	-0.3%	-0.1%	0.1%	0.3%
Red cod	-0.0004%	-0.0002%	0.0002%	0.0004%
Paua	-0.10%	-0.04%	0.04%	0.10%
All commercial fishing	-0.4%	-0.2%	0.2%	0.4%
Coastal infrastructure	-0.008%	-0.003%	0.003%	0.008%
Marine tourism and recreation	-0.2%	-0.1%	0.1%	0.2%
Recreational fishing	-0.8%	-0.3%	0.3%	0.8%
Recreational shellfish gathering	-0.09%	-0.04%	0.04%	0.09%
Recreational use of beaches	-0.7%	-0.3%	0.3%	0.7%
Indigenous biodiversity	-0.2%	-0.1%	0.1%	0.2%
Vessel fuel efficiency	-0.13%	-0.05%	0.05%	0.13%
Scenario M (mandatory standards in Australia and California)				
Initial incursion response	-0.04%	-0.02%	0.02%	0.04%
Greenshell mussels	-20.9%	-8.4%	8.4%	20.9%
Pacific oysters	-1.4%	-0.6%	0.6%	1.4%
King salmon	-1.2%	-0.5%	0.5%	1.2%
All aquaculture	-23.5%	-9.4%	9.4%	23.5%
Snapper	-0.4%	-0.1%	0.1%	0.4%
Red cod	-0.0004%	-0.0002%	0.0002%	0.0004%
Paua	-0.10%	-0.04%	0.04%	0.10%
All commercial fishing	-0.5%	-0.2%	0.2%	0.5%
Coastal infrastructure	-0.008%	-0.003%	0.003%	0.008%
Marine tourism and recreation	-0.2%	-0.1%	0.1%	0.2%
Recreational fishing	-0.8%	-0.3%	0.3%	0.8%
Recreational shellfish gathering	-0.09%	-0.04%	0.04%	0.09%
Recreational use of beaches	-0.7%	-0.3%	0.3%	0.7%
Indigenous biodiversity	-0.2%	-0.1%	0.1%	0.2%
Vessel fuel efficiency	-0.09%	-0.04%	0.04%	0.09%

Adopting 25% smaller (greater) production impacts on all three aquaculture fisheries decreases (increases) the estimated additional net benefits of the proposed IHS by 24%, to $661 million under Scenario V and $398 million under Scenario M ($1 billion and $642 million respectively).

Given that most of the benefits of the proposed IHS are estimated to be avoided impacts on aquaculture, weaker or stronger future growth in this sector than the 7% annual average assumed has a large effect on the additional net benefits of the proposed IHS.

Table 33 Additional net benefits of proposed IHS with adoption of weaker or stronger aquaculture sector growth rate
Additional present value total net benefits of proposed IHS to year 50, $ million, in 2012 prices and present values

	Average annual growth rate to 2025			
	3.5%	**5%**	**7%**	**10%**
Scenario V (voluntary standards in Australia and California)				
Net benefits	586.0	692.6	**864.6**	1,205.3
Scenario M (mandatory standards in Australia and California)				
Net benefits	354.5	417.7	**520.1**	722.0

The above sensitivity analysis indicates that the main results reported in Section 3.2 above are reasonably robust to adoption of lower or higher values for each of the costs and benefits modelled. Although their magnitude is affected (especially by changes in action costs to non-compliant vessels and avoided impacts on aquaculture), the additional net benefits of the proposed IHS remain positive and substantial throughout.

3.4.3 Costs and benefits

Even with *all* of the costs 25% higher and *all* of the benefits 25% lower than modelled, the proposed IHS is still indicated to provide substantially higher net benefits than the voluntary standard of the baseline scenario, as shown in Table 34. Indeed, the net benefits remain positive even with all the costs four times the size and all the benefits only a quarter of the size modelled.

Table 34 Additional net benefits of proposed IHS with adoption of lower or higher unit costs and benefits
Additional present value total net benefits of proposed IHS to year 50, $ million, in 2012 prices and present values

	Change in unit costs and benefits					
Costs	**+300%**	**+25%**	**+10%**	**Main**	**-10%**	**-25%**
Benefits	**-75%**	**-25%**	**-10%**	**results**	**+10%**	**+25%**
Scenario V (voluntary standards in Australia and California)						
Net benefits	64.5	628.4	770.1	**864.6**	954.1	1,100.9
Scenario M (mandatory standards in Australia and California)						
Net benefits	49.3	379.	463.8	**520.1**	576.4	660.9

The additional net benefits of the proposed IHS remain positive and substantial even with adoption of a higher discount rate that reflects a more commercial perspective.

Table 35 Additional net benefits of proposed IHS with adoption of lower or higher discount rate
Additional present value total net benefits of proposed IHS to year 50, $ million, in 2012 prices and present values

		Discount rate				
		3.5%	**6%**	**8%**	**10%**	**12%**
Scenario V (voluntary standards in Australia and California)						
Net benefits	3,016.0	1,454.9		**864.6**	540.9	354.4
Scenario M (mandatory standards in Australia and California)						
Net benefits	1,719.7	854.0		**520.1**	333.5	223.7

3.4.4 MPI inputs

Other inputs of particular interest are vessel compliance and action rates and the rates of introduction and spread of species introduced by vessel biofouling.

As highlighted in Section 2.6.4, vessel compliance and action rates and species introduction rates are interrelated. Higher rates of action against non-compliant vessels would encourage higher uptake of compliance. Higher compliance would also reduce the proportion of noncompliant vessels, to which action rates would apply. In addition, compliance and action rates would together affect the rates of introduction of new species by vessel biofouling. We therefore cannot analyse the sensitivity of the estimated additional net benefits of the proposed IHS to these three inputs independently, but only in combination. Higher (lower) compliance and action rates could be expected to result in lower (higher) introduction rates.

Furthermore, for the purpose of the CBA, we are interested in how vessel compliance and action rates and species introduction rates differ between the proposed IHS and the baseline scenario's voluntary standard.

Table 36 shows combinations of higher (lower) compliance and action rates and lower (higher) introduction rates under either the voluntary standard only, the proposed IHS only or both. We do not include 25% higher compliance rates because, for some vessel types, these would exceed 100% compliance. The additional net benefits of the proposed IHS would be higher than estimated if 5% or 10% higher compliance and action rates under the proposed IHS could achieve 5% or 10% lower introduction rates (thereby incurring higher costs, but achieving much higher benefits), or, alternatively, if 5%, 10% or 25% lower compliance and action rates under the voluntary standard resulted in 5%, 10% or 25% higher introduction rates (incurring lower costs, but delivering much lower benefits). Only if compliance and action rates were 25% lower and resulted in 25% higher introduction rates under the proposed IHS only, under mandatory standards in Australia and California, would the proposed IHS provide lower net benefits than the voluntary standard ($80 million less).

Table 36 Additional net benefits of proposed IHS with adoption of lower or higher vessel compliance and action rates and species introduction rates
Additional present value total net benefits of proposed IHS to year 50, $ million, in 2012 prices and present values

	Changes in rates					
Compliance and action rates	**+10%**	**+5%**	**Main**	**-5%**	**-10%**	**-25%**
Introduction rates	**-10%**	**-5%**	**results**	**+5%**	**+10%**	**+25%**
Scenario V (voluntary standards in Australia and California)						
Under voluntary standard only	522.3	693.5	**864.6**	1,035.8	1,206.9	1,720.3
Under proposed IHS only	1,149.8	1,007.0	**864.6**	722.7	581.3	159.8
Under both	807.5	835.8	**864.6**	893.9	923.6	1,015.5
Scenario M (mandatory standards in Australia and California)						
Under voluntary standard only	258.3	389.2	**520.1**	651.0	781.8	1,174.5
Under proposed IHS only	763.9	641.7	**520.1**	399.0	278.4	-80.1
Under both	502.1	510.8	**520.1**	529.9	540.2	574.3

Finally, adopting faster rates of spread (i.e. fewer years to complete spread) for all introduced species modelled increases the estimated additional net benefits of the proposed IHS by bringing forward the benefits, in terms of the avoided impacts of these introduced species on affected sectors. Adopting faster (slower) rates of spread has a greater effect in aquaculture and commercial fishing than in the coastal environment. Even with 25% slower rates of spread (i.e. 25% more years to complete spread) in all three environments, the proposed IHS is still estimated to deliver substantially greater net benefits than the baseline scenario's voluntary standard.

Table 37 Additional net benefits of proposed IHS with adoption of slower or faster rates of spread of introduced species
Additional present value total net benefits of proposed IHS to year 50, $ million, in 2012 prices and present values

	-25%	**-10%**	**Main results**	**+10%**	**+25%**
Scenario V (voluntary standards in Australia and California)					
In aquaculture and commercial fishing	920.6	885.4	**864.6**	845.4	819.8
In coastal environment	871.1	867.0	**864.6**	862.5	859.8
All environments	927.1	887.8	**864.6**	843.4	815.0
Scenario M (mandatory standards in Australia and California)					
In aquaculture and commercial fishing	553.0	532.3	**520.1**	508.7	493.6
In coastal environment	524.0	521.5	**520.1**	518.8	517.2
All environments	556.9	533.8	**520.1**	507.5	490.7

4 References

Anderson, C., Atlar, M., Callow, M., Candries, M., Milne, A. and Townsin, R.L. (2003) The development of foul-release coatings for seagoing vessels**,** in *Journal of Marine Design and Operations*, no.B4, http://www.biosciences-labs.bham.ac.uk/callowj/ent/Atlar%20et%20al_IMarest%202004.pdf

Aquaculture New Zealand (2012*) New Zealand Aquaculture 2012 – A Sector Overview with Key Facts, Statistics and Trends*, http://aquaculture.org.nz/2012/05/29/new-zealandaquaculture-facts-2012/

Beenstock, M. and Vergottis, A. (1993) *Econometric Modelling of World Shipping*, Chapman and Hall.

California State Lands Commission (2012) *Biofouling Management Regulations for Vessels Operating in California Waters,* revised text of proposed regulations, as at 7 June 2012, http://www.slc.ca.gov/spec_pub/mfd/ballast_water/Documents/Attachment_2_Biofouling_7Ju ne12.pdf

Coriolis (2012) *Food and Beverage Information Project 2011 – Industry Snapshot*, http://www.med.govt.nz/sectors-industries/food-beverage/pdf-docs-library/informationproject/food-beverage-information-project-2011-industry-snapshot-february-2012.pdf

Davey, N.K., Cole, R.G. and Cairney, D.G. (2006) *Survey of Marine Recreational Fishing Along the West Coast, South Island*, NIWA, report to the Ministry of Fisheries, http://www.fish.govt.nz/NR/rdonlyres/7EC1908F-9715-4F75-905644365A8617A2/0/RECWG200701WestcoastrecsurveyFRR2.pdf

Deep Sea News (2010) *The Future in Ship Design*, April 2010, http://deepseanews.com/2010/04/the-future-in-ship-design/

Environment Waikato (2006) *Buffalo Beach Coastal Erosion Management Strategy*, Technical Appendices, Appendix F Economic Analysis, http://www.waikatoregion.govt.nz/Services/Publications/Technical-Reports/Buffalo-BeachCoastal-Erosion-Management-Strategy-Part-II-Technical-Appendices/

Environmental Protection Agency (2009) *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Category 3 Marine Diesel Engines*, Chapter 7 – Economic Impact Analysis, United States of America, http://www.epa.gov/nonroad/420r09019-chp07.pdf

Her Majesty's Treasury (2011) *The Green Book – Appraisal and Evaluation in Central Government*, amended version of July 2011, http://www.hmtreasury.gov.uk/d/green_book_complete.pdf

International Maritime Organization (2011a) *2011 Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species*, http://www.imo.org/blast/blastDataHelper.asp?data_id=30766&filename=207%2862%29.pdf

International Maritime Organization (2011b) *Biofouling Management Plan* and *Biofouling Record Book*, http://www.international-marine.com/invasivespecies/IMO-Biofouling-Guidelines.aspx

International Maritime Organization (2011c) *Resolution of the Marine Environment Protection Committee 203(62) – Amendments to the Annex of the Protocol of 1997 to Amend the International Convention for the Prevention of Pollution from Ships, 1973, as Modified by the Protocol of 1978 Relating Thereto*, adopted 15 July 2011, http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Technical%20and%20Operational%20Measures/Resolution%20MEPC.203%2862%29.pdf

Kerr, G.N. and Latham, N. (2011) *The Value of Recreational Inshore Marine Fishing*, paper presented at the 2011 Conference of the New Zealand Agricultural and Resource Economics Society, 25 to 26 August 2011, Nelson, New Zealand, http://ageconsearch.umn.edu/bitstream/115408/2/Kerr.pdf

Kite-Powell, H.L. and Hoagland, P. (2002) *Economic Aspects of Right Whale Ship Strike Management Measures*, report to the National Marine Fisheries Service, National Oceanic and Atmospheric Administration, April, 2002, http://www.nero.noaa.gov/shipstrike/subinfo/shipstrikeeconapril02.pdf

Market Economics (2008) *Economic Impacts of the 2007-2008 New Zealand Cruise Ship Season*, report prepared for Cruise New Zealand, http://www.tourismnewzealand.com/media/118443/cruise%20new%20zealand%20economic%20impact%20assessment%202007-2008.pdf

Meyrick and Associates (2007) *International and Domestic Shipping and Ports Study*, report to Department for Transport, Energy and Infrastructure, South Australia, http://www.atcouncil.gov.au/documents/files/International_and_Domestic_Shipping_and_Ports_Study.pdf

Millennium Ecosystem Assessment (2003) *Ecosystems and Human Well-Being: a Framework for Assessment*, http://www.maweb.org/en/Framework.aspx

Ministry for Primary Industries (2012) *New Zealand Fisheries InfoSite*, accessed May 2012, http://fs.fish.govt.nz/Page.aspx?pk=6&tk=97

Ministry for the Environment (2005) *Energy Efficient Ways – to Improve the Bottom Line of your Fishing Business,* http://www.energyfed.org.nz/Fishing.pdf

Ministry for the Environment (2007) *Environment New Zealand 2007*, Chapter 11: Oceans, http://www.mfe.govt.nz/publications/ser/enz07-dec07/

Ministry of Agriculture and Forestry (2002) *Cost-Benefit Analysis of Unwanted Organism or Pest Response Options*, http://brkb.biosecurity.govt.nz/search/query/costbenefit+analysis+of+unwanted+organism+or+pest

Ministry of Agriculture and Forestry (2005) *Import Health Standard for Ships' Ballast Water from All Countries*, http://www.biosecurity.govt.nz/files/ihs/ballastwater.pdf

Ministry of Agriculture and Forestry (2010) *The Biosecurity Risks Associated with Biofouling on International Vessels Arriving in New Zealand: Summary of the Patterns and Predictors of Fouling*, March 2010.

Ministry of Agriculture and Forestry (2011) *Risk Analysis: Vessel Biofouling*, February 2011, http://www.biosecurity.govt.nz/files/regs/imports/risk/vessel-biofouling-risk-analysis-0211.pdf

Ministry of Agriculture and Forestry (2012a) *Import Health Standard Applicable to Biofouling on Vessels from All Countries*, draft of April 2012.

Ministry of Agriculture and Forestry (2012b) *Guidance Document to the Import Health Standard for Vessel Biofouling*, draft of April 2012.

Ministry of Economic Development (2012) *Key Tourism Statistics*, May 2012, http://www.med.govt.nz/about-us/pdf-library/tourism-publications/Nature%20Based%20Tourism%20Profile%20-122KB%20PDF.pdf

Ministry of Tourism (2009) *Tourist Activity – Nature-Based Tourism*, Tourism Sector Profile, Series B3, August 2009, http://www.med.govt.nz/about-us/pdf-library/tourismpublications/Nature%20Based%20Tourism%20Profile%20-122KB%20PDF.pdf

Nathan Associates (2007) *Calculating Tariff Equivalents for Time in Trade*, report prepared for United States Agency for International Development, http://www.tcboostproject.com/_resources/resource/Calculating%20Tariff%20Equivalents%20for%20Time%20in%20Trade.pdf

National Ocean Economics Program (2006) *Florida's Ocean and Coastal Economies Report*, California State University Monterey Bay, http://www.floridaoceanscouncil.org/reports/Florida_Ocean_&_Coastal_Eco.pdf

New Zealand Aquaculture Council (2006) *The New Zealand Aquaculture Strategy*, http://www.aquaculture.govt.nz/files/nz_aquaculture_strategy/NZ_Aquaculture_Strategy.pdf

New Zealand Government (2008) *Aquaculture in New Zealand,* http://www.aquaculture.govt.nz/files/pdfs/Aqua_NZ.pdf

Nimmo Bell (2008) *Choice Modelling to Estimate Indigenous Biodiversity Values for a Coastal Marine Ecosystem – Reallocation or Special Tax?*, paper presented at the 2008 Conference of the New Zealand Agricultural and Resource Economics Society, Nelson, New Zealand, http://nimmo-bell.co.nz/pdf/forst/WP7NZARESNelsonAug08ChoiceModellingReallocationorSpecialTax.pdf

NIWA (2010a) *Milestone Report – Milestone Number 3.2.2: Passenger Vessels*, September 2010.

NIWA (2007) A window on recreational fisheries, in *Fisheries & Aquaculture Update,* no.23, http://www.niwa.co.nz/news-and-publications/publications/all/fau/2007-23/recreational NIWA (2010b) *Milestone Report – Milestone Number 3.2.3: Fishing Vessels*, October 2010.

NIWA (2010c) *Milestone Report – Milestone Number 3.2.1: Recreational Vessels*, September 2010.

NIWA (2011) *Milestone Report – Milestone Number 3.2.4: Merchant Vessels*, January 2011.

Notteboom, T. (2006) The time factor in liner shipping services, in *Maritime Economics and Logistics*, vol.8, no.1, http://www.porteconomics.eu/publications/journal-papers.html

Notteboom, T. and Carriou. P. (2009) *Fuel Surcharge Practices of Container Shipping Lines: Is it about Cost Recovery or Revenue Making?*, paper presented at 2009 conference of the International Association of Maritime Economists, 24 to 26 June 2009, Copenhagen, Denmark, http://www.porteconomics.eu/downloads-section/doc_details/278-2009iamenotteboom-a-cariou.html

OECD (2011) *Maritime Transport Costs Database*, http://stats.oecd.org/Index.aspx?datasetcode=MTC

Oum, T.H., Waters III, W.G. and Yong, J.S. (1990) *A Survey of Recent Estimates of Price Elasticities of Demand for Transport*, working paper, Transportation Division, Infrastructure and Urban Development Department, World Bank, http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/1990/01/01/000009265_3960928230924/Rendered/PDF/multi_page.pdf

Pacific Logistics (2011) *2011 Freight Charge Comparison Report*, report to the Ministry of Transport, http://www.transport.govt.nz/research/Documents/UTCC-2011-Freight-ChargeComparison-Report-Aug-2011.pdf

Patterson, M. and Cole, A. (1999) *Assessing the Value of New Zealand's Biodiversity*, Occasional Paper no.1, School of Resource and Environmental Planning, Massey University, February 1999.

Pendleton, L., Kildow, J. and Rote, J.W. (2006) The non-market value of beach recreation in California, in *Shore & Beach*, vol.74, no.2, Spring 2006, http://www.oceaneconomics.org/Download/

Port of Tauranga (2011) *Annual Report 2011*, Financial Statements, http://www.porttauranga.co.nz/Investors/Financial-Information/Download-Annual-Report/

PricewaterhouseCoopers (2011) *Proposed Australian Biofouling Management Requirements – Consultation Regulation Impact Statement*, prepared for the Department of Agriculture, Fisheries and Forestry, http://www.daff.gov.au/__data/assets/pdf_file/0018/2061207/Biofouling-Consultation-RIS.pdf

Public Policy Institute of California (2003) *Special Survey on Californians and the Environment*, http://www.ppic.org/content/pubs/survey/S_1103MBS.pdf

Reserve Bank of New Zealand (2012) *Exchange Rates*, monthly average, accessed May 2012.

Seafood Industry Council and Energy Efficiency and Conservation Authority (2010) *Energy Efficiency Handbook for Inshore Vessels*, http://www.seafoodindustry.co.nz/f464,88826/88826_EnergyEfficiency.pdf

Schischka, T. and Marsh, D. (2008) *Shared Fisheries: Results from an Investigation into the Value of the Recreational and Commercial Catch in a New Zealand Quota Management Area*, paper presented to the 2008 conference of the Australian Agricultural and Resource Economics Society, 6 to 8 February, 2008, Canberra, Australia.

Schultz, M.P., Bendick, J.A., Holm, E.R., and Hertel, W.M. (2011) Economic impact of biofouling on a naval surface ship, in *Biofouling*, vol.27, no.1, January 2011, http://www.slc.ca.gov/spec_pub/mfd/ballast_water/Documents/Schultz%20et%20al%20%20 2011.pdf

SPARC (2009) *Sport and Recreation Participation Levels – Findings from the 2007/2008 Active New Zealand Survey*, http://www.activenzsurvey.org.nz/

Statistics New Zealand (2006) *New Zealand's Marine Economy 1997-2002*, http://www.stats.govt.nz/browse_for_stats/environment/natural_resources/marine.aspx

Statistics New Zealand (2007) *Are New Zealanders Living Closer to the Coast?*, http://www.stats.govt.nz/browse_for_stats/population/Migration/internal-migration/are-nzliving-closer-to-coast.aspx)

Statistics New Zealand (2010) *Fish Monetary Stock Account 1996-2009*, http://www.stats.govt.nz/browse_for_stats/environment/natural_resources/fish-monetarystock-account-1996-2009.aspx

Statistics New Zealand (2012a) *Overseas Cargo Statistics*, accessed May 2012.

Statistics New Zealand (2012b) *Consumer Price Index*, all goods, accessed May 2012.

Statistics New Zealand (2012c) *Gross Domestic Product*, expenditure measure, accessed May 2012.

Taranaki Regional Council (2008) *Recreational Use of Coast, Rivers and Lakes in Taranaki 2007-2008*, http://www.trc.govt.nz/assets/taranaki/region-andcouncil/Region/pdf/waterrecreationsurvey.pdf

Treasury (2008) *Public Sector Discount Rates for Cost Benefit Analysis*, www.treasury.govt.nz/publications/guidance/planning/costbenefitanalysis/discountrates

Vidal, W. (2010) Modern cargo ships slow to the speed of the sailing clippers, in *The Observer*, 25 July 2010, http://www.guardian.co.uk/environment/2010/jul/25/slow-ships-cutgreenhouse-emissions

Williamson, I. (2008) The psychology of customs and quarantine, in *The Coastal Passage*, no.33, http://www.thecoastalpassage.com/psycocustoms.html

Wilson, J.D.K. (1999) *Fuel and Financial Savings for Operators of Small Fishing Vessels*, Food and Agriculture Organization Fisheries Technical Paper 383, ftp://ftp.fao.org/docrep/fao/007/x0487e/x0487e00.pdf

World Shipping Council (2008) *Record Fuel Prices Place Stress on Ocean Shipping*, May 2008, http://www.worldshipping.org/pdf/WSC_fuel_statement_final.pdf