Proposed Australian Biofouling Management Requirements

Consultation Regulation Impact Statement

Department of Agriculture Fisheries and Forestry
December 2011

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Abbreviations

Abbreviation	Description
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences (A division of DAFF)
AFMA	Australian Fisheries Management Authority
APEC	Asia Pacific Economic Cooperation
DAFF	Department of Agriculture, Fisheries and Forestry
DoFD	Department of Finance and Deregulation
eQPAR	Electronic Quarantine Pre-arrival Report
IMO	International Maritime Organization
MGRA	Marine Growth Risk Assessment
NIMS	Non-Indigenous Marine Species
NPV	Net Present Value
O/S	Overseas
OBPR	Office of Best Practice Regulation
OOW	Out of Water
PV	Present Value
SBRA	Species Biofouling Risk Assessment
SOC	Species of Concern

Executive summary

Biofouling is the accumulation of microorganisms, algae, plants and animals on submerged surfaces. Biofouling on vessels provides the opportunity for these organisms to be transported and establish outside their natural range with potentially significant adverse economic and environmental impacts.

These include impacts on:

- marine based industries such as commercial fishing, tourism and marine farming
- port infrastructure and access
- human health through diseases or infection such as septicaemia
- environmental biodiversity
- social and cultural values of the marine environment.

Many species have already become established in Australia and overseas. Known as non-indigenous marine species (NIMS), examples in Australia include:

- the Northern Pacific seastar – it has affected the scallop and mussel fisheries and aquaculture in Tasmania. In 2000, very large numbers of the seastar on the Tasmanian east coast were reported to have resulted in a $1 million loss to the scallop industry (Australian Government, 2008a)
- the European fan worm – this species was first identified in Australian waters in 1965 and is now established along all Australian coastlines except Queensland (QLD) and the Northern Territory (NT). It has the ability to physically alter native marine ecosystems and outcompete native and commercial species for food and habitat which can affect fishery and aquaculture productivity as well as tourism industries that rely on marine biodiversity (Australian Government, 2008b).

More substantial impacts have been reported overseas in some instances. For example, the Asian clam has become established in the United States of America (USA). It clogs industrial water intake pipes and outcompetes native species. Damages and control costs are estimated at US$1 billion annually (ISSG, 2005).

These examples show that NIMS have been transported through biofouling of vessels for many years. While the identified risks cannot be eliminated, they can be managed. There are some measures already in place to manage associated risks at the Commonwealth and at the State and Territory level.

This consultation Regulation Impact Statement (RIS) explores the costs and benefits of options for managing the risk of more NIMS associated with biofouling becoming established in the Australian marine environment.

Problems with the current approach

The current arrangements for managing the risk of establishment of NIMS associated with biofouling in Australia do not provide a consistent or comprehensive approach. All Australian states and territories have legislation that enables government authorities to protect their coastal waters from NIMS, yet the extent to which it is applied is limited. For most jurisdictions, the detection and identification of NIMS is by chance or through other compliance mechanisms, rather than by undertaking a targeted risk management approach specific to biofouling risks.

Extensive research has been undertaken on how NIMS are introduced and the risks they present, yet most jurisdictions lack operating procedures outlining which vessels will be targeted, how vessel risks will be assessed, and in some cases, which species are of most concern and why. Consequently, inconsistencies between the content and degree of application of this jurisdictional legislation render the current jurisdiction-based biofouling management strategy largely ineffective at the national level.

Options

Two options for Australian Government action to manage the risks of biofouling associated establishment of NIMS have been developed and analysed:

- Option 1: introduce regulations – these regulations would impose restrictions on vessels assessed to be in proposed extreme or high risk categories when they enter Australian waters. Restrictions on the time they are able to spend in Australian ports and waters as well as other requirements may be imposed depending on their risk categorisation and any actions they take to reduce the risk.

- Option 2: implement an education program to encourage improved voluntary biofouling management – The program would target the owners, operators and agents of vessels arriving from international waters, raise awareness of the threats associated with marine pests and encourage owners and operators of vessels to adopt recommended practices that are set out in national guidance documents.

These options are compared with a base case in which no new legislation or regulation is introduced at the Commonwealth level. The base case does account for the possibility that some jurisdictions, specifically Western Australia (WA) and the NT, could introduce new jurisdiction specific approaches.

This base case also incorporates the dissemination and public availability of international guidelines on biofouling that have recently been approved.

Impact analysis

The costs and benefits of each of the options have been analysed.

There are considerable uncertainties associated with the assumptions and data relied on to estimate the costs of option 1 and so feedback is sought as part of the consultation process on the assumptions and on whether better information may be available to help refine the estimates.

The costs of option 1 would nearly all be borne by vessel operators and include costs of DAFF Biosecurity interviews (formerly Australian Quarantine and Inspection Services interviews), inspections, treatments and cleaning of vessels. Two sets of costs are presented to account for the possibility that WA and the NT may introduce their own approaches which would partially offset the additional costs of introducing a national approach—the actual costs and benefits could be somewhere between these depending on the approach adopted by these jurisdictions.

It is even more challenging to quantify the benefits of reducing the risk of NIMS establishing than the costs. A number of examples of benefits (or avoided costs) are outlined and one approach to estimating economic benefits has been modelled which is considered to represent the upper bound of possible economic benefits. Together, these canvas the avoided costs of adverse impacts on marine based industries such as tourism, fishing and marine farming, avoided health impacts and the non-use benefits associated with marine resources among other benefits.

Given the uncertainties in the assumptions and limitations in data used to quantify costs and benefits, the results of the analysis, summarised below, should be considered cautiously.

Summary of costs and benefits directly attributed to Commonwealth regulations (option 1)

Cost/benefit item	NPV ($M2011, FY11) No comparable regulations in WA & NT	NPV ($M2011, FY11) Comparable regulations in WA & NT
Costs		
Inspection/Interview Costs	$106.1M	$69.0M
Treatment Costs	$98.0M	$63.7M
Total Costs	**$204.1M**	**$132.7M**

Cost/benefit item	NPV ($M2011, FY11) No comparable regulations in WA & NT	NPV ($M2011, FY11) Comparable regulations in WA & NT
Benefits		
Commercial fishing	$111.7M	$72.6M
Marine tourism and recreation	$174.2M	$113.2M
Total Benefits	**$285.9M**	**$185.8M**
Net impact		
Total Net Benefits	81.8M	53.1M
Benefit cost Ratio	1.4	1.4
Non-use benefits	**Evidence suggests highly positive for a number of marine regions**	

The costs for the education program (option 2) are much less than the costs of the regulatory approach and the costs of the program itself would be borne by Government. Some vessel operators may incur costs voluntarily in response to the program but it is estimated that the behavioural change would be much less than for option 1.

The benefits would also be much less. However, given some costs, such as DAFF Biosecurity inspections, would not be incurred under the voluntary approach, the ratio of benefits to costs for option 2 is greater than for option 1. The ratio of benefits and costs also varies depending on whether WA and NT implement comparable regulations. This is because the costs to government of the program remain the same under either scenario but the other costs and benefits vary in proportion to the number of vessels affected.

Summary of cost and benefits directly attributed to a Commonwealth educational campaign (option 2)

Cost/benefit item	PV ($2011M, FY11) No comparable regulations in WA & NT	PV ($2011M, FY11) Comparable regulations in WA & NT
Costs		
Voluntary Guidelines		
Costs to government	$2.3M	$2.3M
Costs to vessel operators	$3.2M	$2.1 M
Total Costs	**$5.4M**	**$4.4M**
Benefits		
Commercial fishing	$9.6M	$6.2M
Marine tourism and recreation	$15.0M	$9.8M
Total Benefits	**$24.6M**	**$16.0M**
Net impact		
Total Net Benefit	**$19.2M**	**$11.6M**
Benefit Cost Ratio	**4.5**	**3.6**

Sensitivity analysis has been undertaken by varying the assumptions and identifying the impact this has on the modelled estimates. This showed that varying key assumptions does have a significant impact on the results and in some cases results in a benefit cost ratio of less than one.

The most significant impact results from varying assumptions about the economic value at risk. The modelled scenario assumes that a severe impact on the fishing industry and Great Barrier Reef is avoided. If the value at risk is halved, the BCR for option 1 falls from 1.4 to 0.7. This reinforces the need for caution in interpreting the results and that there is uncertainty about whether the benefits do outweigh the costs. Feedback is specifically sought on the methodology for calculating the value at risk.

Summary of findings and recommendations

The intent of government action in relation to biofouling is to manage risk rather than a known quantity or impact. The analysis suggests that regulation will mitigate the risk to a much greater extent than the voluntary option but this comes at a much higher cost. These costs could be outweighed by the benefits given the possible range of benefits that have been identified but this is not certain.

The relatively low costs of option 2, the education program, mean that any small change in behaviour as a result of the program is likely to generate benefits that outweigh the costs but the overall risk is unlikely to be reduced to a great extent.

Despite the limitations of the analysis, option 1 (the regulatory option) is recommended subject to the outcomes of public consultation. This is because it is more likely to substantively contribute to reducing the risk of NIMS establishing in Australia’s marine environment than the education program.

A further consideration is international developments. Now that international guidelines have been approved, global awareness of the risks of biofouling has increased. Some other jurisdictions, including California in the USA and New Zealand are planning to introduce regulations. It is also foreseeable, but by no means certain, that an international treaty could be developed. If regulations were adopted in the locations where vessels travelling to Australia mostly originate, such as Asia, the costs and benefits that could be attributed to a regulatory approach in Australia would be less. Given uncertainty that this will occur, these impacts have not been modelled.

This international activity may also create additional incentive for Australia to implement a regulatory regime consistent with international guidelines. Option 1 has intentionally been developed to be consistent with the international guidelines.

1 This consultation regulation impact statement

PricewaterhouseCoopers (PwC) has been engaged by the Department of Agriculture, Fisheries and Forestry (the Department) to prepare this Consultation RIS examining options for the management of risks associated with biofouling from vessels entering Australia.

1.1 Purpose

This Consultation RIS follows the Australian Government Office of Best Practice Regulation (OBPR) Guidelines. The purpose of the RIS is to:

- establish the problem that government is seeking to address
- identify a set of alternative policy options to address this identified problem
- assess the cost and benefits of these options, and the effectiveness of each option in addressing the problem
- on the basis of the analysis, establish a preferred option for government action.

Both regulatory and non-regulatory approaches are canvassed as well as a base case or ‘no change’ option (recognising that not all problems have a cost effective solution through government action).

The Consultation RIS is provided to stakeholders for comment. Particular stakeholder input is sought on those areas where further data are needed and/or where assumptions made in the analysis need to be verified and agreed on.

1.2 Report structure

This RIS is structured as follows:

- Chapter 2 provides background and policy context for the RIS
- Chapter 3 describes the problem that governments are seeking to address
- Chapter 4 establishes the objective of government action
- Chapter 5 describes the policy options being considered in this RIS
- Chapter 6 assesses the costs and benefits of each option
- Chapter 7 summarises the findings.

Appendices:

Appendix A	Research findings on NIMS introduction and impact
Appendix B	Species of concern
Appendix C	Current legislation for managing marine pests
Appendix D	Cost benefit assumptions
Appendix E	Economic studies of non-use values
Appendix F	Establishment rate
Appendix G	Glossary of terms
Appendix H	References.

1.3 Opportunities to comment on this consultation RIS

The Department now seeks input from stakeholders on the proposals outlined in this RIS. The RIS is subject to a 90 day consultation period and the Department welcomes feedback on the recommended option for implementation and any other aspect of the RIS document.

Stakeholders should indicate if their submission is confidential and/or clearly indicate sections that may contain confidential or sensitive information that is not for publication.

The closing date for submissions is [to be agreed].

Responses to the RIS can be lodged as follows:

In writing
Invasive Marine Species Program
Department of Agriculture Fisheries and Forestry
GPO Box 858
Canberra City ACT 2601
Australia

By email
IMS_Program@daff.gov.au

This RIS seeks particular feedback on the following questions (which are repeated in relevant sections of the remainder of the RIS).

Questions for stakeholders

1. Do the proposed operating time restrictions on vessels achieve an appropriate balance between minimising biological risk (which increases with time) and minimising the impact on vessel operators (who may need more time)? If not, why and what would be a better balance?
2. How might vessel operators' behaviour change in response to the proposed regulations?
3. What specific types of flow-on costs and benefits to the Australian economy of the proposed regulations might be significant?
4. The estimates of costs are based on average vessel numbers from 2002–2009. Is there any activity or trends that suggest any significant change in vessel movement or increased numbers of arrivals?
5. Are the cost assumptions consistent with industry experience? (see Appendix D for all cost assumptions). Are there better estimates of costs available?
6. Are the other assumptions used to estimate costs and benefits reasonable based on industry experience? If not, how could they be improved?
7. The methodology for estimating the economic value at risk relies on a series of assumptions about the value of commercial fishing and the Great Barrier Reef. Are there more plausible assumptions or approaches that could be used?
8. What other evidence is there of the potential impacts of non indigenous marine species becoming established in Australia?
9. What is industry's view of the likely effectiveness of a voluntary approach to reducing the risks associated with biofouling compared with a regulatory approach?

2 Background and context

Biofouling is the accumulation of microorganisms, algae, plants and animals on submerged surfaces. Biofouling on vessels provides the opportunity for these organisms to be transported and establish outside their natural range with potentially significant adverse economic and environmental impacts.

The following sections:

- briefly describe marine species that establish outside their range, known as non-indigenous marine species (NIMS) and the range of potential adverse impacts they can have;
- outline how these species can be transported to the Australian marine environment as biofouling on vessels.

2.1 Non-Indigenous marine species and their impacts

NIMS are species of plants or animals that are introduced to the marine environment outside their natural range. Introduced species can result in direct or indirect damage to:

- commercial fisheries and aquaculture through adverse impacts on native or farmed species or closure of fisheries
- the tourism industry through reducing the amenity of attractions such as reefs or enjoyment of the marine environment because of increased risks of disease
- infrastructure through biofouling of port facilities, navigation aids, water pipe systems and hydroelectric plants
- the commercial efficiency of ports, including if a port is closed due to declaration of a quarantine area
- environmental biodiversity
- human health through diseases or infection such as septicaemia
- the amenity and non-use value of the marine environment relating to existence, bequest and option values.

In Australia, approximately 450 marine species are estimated to be established that are non-indigenous or whose origins are unknown (Hewitt 2011). Studies have shown that up to 69 per cent of these are associated with biofouling (Hewitt *et al.*, 2010, 2004, 1999). It is predicted that 3–4 new NIMS will continue to establish in Australian waters each year (Hewitt, 2011).

Of all known NIMS, 56 have been identified as species of concern (SOC) (Hewitt *et al.*, 2011a). SOC are considered the most likely to arrive and cause significant negative impacts on Australia's maritime industries and environment if established. These species are discussed further in Chapter 3 and listed in Table 17 (Appendix B).

The loss of revenue resulting from the establishment of NIMS and the costs associated with control or eradication efforts are internationally significant (refer to Table 16, Appendix A). For example, the damages and costs associated with controlling NIMS in the USA are estimated to amount to US$14.2 billion annually (Pimentel *et al.*, 2005). Importantly, many of the most internationally, economically significant NIMS are not yet known to have established in Australian waters.

The likelihood of arrival and establishment of these NIMS in Australia is increasing with the rising number of international vessel arrivals (Davidson *et a.*, 2009). There is legitimate and increasing concern that the introduction of some of the most potentially harmful NIMS will affect the Australian economy and environment, and could negatively affect human health, social and cultural values.

2.1.1 Biofouling accumulation and establishment

The geographical range of marine species does expand naturally over evolutionary time (tens to thousands of years). However, human activities within the marine environment have accelerated these range expansions (weeks to years) and extended the geographic boundaries beyond the limits of natural processes (Hewitt *et al.*, 2011a). Marine vessel movement has been identified as the greatest contributor (Hewitt and Campbell, 2010). Mechanisms for NIMS transport by marine vessels include:

- biofouling organisms on vessels and aquaculture equipment (Davidson *et al.*, 2009, Cook, *et al.*, 2008)
- boring into wooden-hulled vessels (Carlton and Hodder, 1995)
- historic use of dry and semi-dry ballast (Ruiz *et al.*, 2000)
- transport of planktonic and pelagic organisms through ballast water
- intentional transfer of aquaculture and mariculture organisms (Fofonoff *et al.*, 2003)
- transfer of live, frozen or dried food products and live aquarium products (Cook *et al.*, 2008).

Biofouling is internationally recognised as the principle mechanism for translocation of NIMS throughout the world and contributes substantially to the costs and damages caused by these species. It is a complex process that begins as soon as a surface is submerged.[1] First, microscopic organisms colonise the surface, which then provides a suitable surface for larger organisms, including molluscs, crustaceans and macro-algae, to settle (Lewis, 1998; Railkin, 2004). The likelihood of a vessel carrying NIMS on its submerged surfaces depends on a number of factors including:

- the quality and suitability of anti-fouling coatings on the surfaces
- time spent in ports where the species are established
- availability of a suitable surface
- speed and duration of the vessel voyage
- various environmental factors (Coutts *et a*l., 2009).

Biofouling accumulation is generally more prolific on niche areas[2] of vessels or on vessels that are stationary for extended periods of time (Hewitt *et al.*, 2011b). Vessels that have accumulated high levels of biofouling are more likely to be associated with the establishment and subsequent negative impacts from NIMS in non-native waters.

This RIS is focused on exploring options for government intervention to reduce the risk of SOC becoming established in Australian waters.

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[1] See Lewis and Coutts (2010) for a conceptual model of the species invasion process.

[2] Niche areas refer to areas on a vessel or movable structure that are more susceptible to biofouling accumulation due to different hydrodynamic forces, susceptibility to anti-fouling coating wear or damage or absence of anti-fouling coatings. They include, but are not limited to, waterline, sea chests, bow thrusters, propeller shafts, inlet gratings, jack-up legs, moon pools, bollards, braces and dry-docking support strips.

3 Statement of the problem

Biofouling on vessels entering Australian waters creates the risk that NIMS and, in particular, SOC will continue to establish in Australia with potentially damaging impacts if nothing is changed. There are a number of aspects to defining the scale and scope of this problem, including:

- the likelihood of a SOC arriving and becoming established
- the consequences of a SOC becoming established
- the effectiveness of existing regulation (including regulation by States and Territories)
- the extent to which existing voluntary national guidelines address the problem
- the implications of international initiatives to address biofouling
- the extent to which industry self manages the problem.

The following sections address each of these in turn and sections 3.7 and 3.8 set out conclusions about the effectiveness of current arrangements and the rationale for government action respectively. Importantly, there are many uncertainties associated with our current understanding of the scale and scope of the problem. International and Australian examples demonstrate potential adverse impacts. However, in many cases these are not quantified. Further, the impacts caused by individual SOC vary widely and their extent and likelihood depends on a range of unpredictable factors.

3.1 The likelihood of SOC becoming established in Australia

The available literature suggests that 1,781 marine and estuarine species worldwide have been introduced and subsequently established outside their native range (Hewitt *et al.*, 2011a).

These provided a starting point for an Australian Government commissioned assessment to identify NIMS and estuarine species that pose a significant biosecurity risk and are not currently established within Australian waters. Species with a recognised invasion history, not currently known to be present in Australian waters and associated with biofouling were identified and further assessed for:

- the likelihood of arrival on a vessel as biofouling in Australian waters
- the potential to establish a population and spread if introduced
- the potential to cause a moderate to extreme impact to one or more of Australia's environmental, economic, human health and social or cultural values.

The analysis identified 56 species that met these criteria (Hewitt *et al.*, 2011a). In addition, it was determined that all 56 species, once introduced, have the potential to survive in some location of Australia. The complete report is available at: www.marinepests.gov.au. The names and associated risk rankings for each of the 56 SOC are listed in Appendix B.

3.1.1 Arrival and establishment of NIMS via marine vessels

The Australian Government commissioned further investigations of the potential for vessels to act as a mechanism for NIMS to be transported and to determine an approximate rate at which the 56 SOC would be expected to arrive within Australian waters if no preventative measures are adopted. Based on best available information, the report estimates that between 3.38 and 4.05 NIMS would be expected to arrive annually and fifteen to twenty per cent of these would be SOC (Hewitt, 2011). There are a large number of unknowns about arrival rates and a range of assumptions needed to be made to arrive at this estimated rate. This included adjustments to account for the higher rate of detection of NIMS since the 1960s relative to earlier periods.

A complete copy of the report is available in Appendix F.

3.1.2 Potential for domestic spread

NIMS have the potential to spread between Australian coastal ecosystems naturally and through human-mediated movements. Natural spread is typically associated with currents, including drift, wind-driven movement, and mobility of some species (Hewitt *et al.*, 2011a).

Once a species becomes established in a high traffic port, or 'transport hub', there is a strong probability that domestic vessels will be colonised by pest species and translocated to more locations across Australia (Carlton and Hodder, 1995, Hewitt *et al.*, 2011b). Analysis of vessel movements shows more than 41 per cent of international vessels entering Australia continue on to one or more domestic ports (Hewitt *et al.*, 2011b). Some of these subsequent port durations exceed 30 days providing opportunities for secondary spread of NIMS (Hewitt *et al.*, 2011a, Hewitt *et al.*, 2011b). This highlights that once established in one location, there is a high probability of spread.

3.2 The consequences of SOC becoming established

The consequences of SOC becoming established are likely to be varied depending on the species and the extent of their spread.

NIMS have probably been establishing in Australian waters for well over 200 years and their past impacts can be helpful in understanding the potential future impacts if new species become established. However, it is not always possible to retrospectively understand the impacts of species that arrived many years ago without detailed information on the affected environment prior to their establishment. Some examples of more recent known arrivals are better documented although the impacts are not always quantified.

The black striped mussel was established and eradicated from three Darwin marinas in 1998. It posed a significant threat to surrounding marine infrastructure including the local $40 million pearl fishing industry (Bax *et al.*, 2002). The eradication cost $2.2 million (Canyon *et al.*, 2002). It is one of few examples of successful eradication of an established population. Its success was due to the ability to close off and treat the port area but resulted in 100 per cent mortality of all living organisms in the treated area.

The National System for the Prevention and Management of Marine Pest Incursions (the National System) includes initiatives for ongoing management and control of established pests. The key initiative is the development and implementation of National Control Plans for agreed pests of concern. There are currently plans in place for six species including the Northern Pacific Seastar and the European fan worm.

The Northern Pacific seastar is widely recognised to cause impacts to scallop and mussel fisheries and aquaculture in Tasmanian waters. Of most concern is the impact on the scallop industry value at about $26 million a year (ABARES, 2010). In 2000, very large numbers of the seastar were reported in collector bags and cages on the east coast of Tasmania resulting in a $1 million loss to the industry (Australian Government, 2008a). The species is also implicated as a contributing factor in the decline of an endangered fish in the Derwent River Estuary. It has the potential to spread along the southern coast of Australia from Sydney to Perth and its impacts on biodiversity and the aesthetic values of the marine environment could potentially affect tourism and recreational values of coastal areas (Australian Government, 2008a).

The European fan worm was first identified in Australian waters in 1965 and is now established along all Australian coastlines except QLD and the NT (Canyon *et al.*, 2002). It has the ability to physically alter native marine ecosystems and outcompete native and commercial species for food and habitat which can affect fishery and aquaculture productivity as well as tourism industries that rely on marine biodiversity. Eradication of the European fan worm is not considered a feasible management option since it would cost up to $263 million because it is so widespread.

The potential costs of implementing the National Control Plans for the six species were estimated to be at least $11 million (Australian Government, 2008b).

The 56 SOC are considered to have potential to cause a moderate to extreme impact on one or more of Australia's environmental, economic, human health and social or cultural values and many have had significant impacts overseas. For example, the Asian clam has become established in the USA. It clogs industrial water intake pipes and outcompetes native species. Damages and control costs in the USA are estimated at US$1 billion (ISSG, 2005). The Chinese mitten crab is established in Germany. Its burrowing activity damages dykes and increases river bank erosion. It preys on commercially important species, clogs water intake filters and destroys commercial shellfish beds. It is estimated to have resulted in costs of €$80 million since 1912 (Gollash, 2006).

Based on available data, it is not possible to predict with accuracy the scope and scale of the impacts of SOC continuing to become established in Australian waters at current rates. However, the examples outlined demonstrate some of the possible impacts and potential costs of these.

3.3 The effectiveness of existing regulation

All states and territories already have some legislation that enables government authorities to act on, and manage marine pest risks. However, there is currently no nationally consistent system in place to prevent their introduction and establishment. Further, with the exception of WA and NT, most states and territories have not formally communicated policies on the application of their legislative powers.

At the Commonwealth level, the *Quarantine Act 1908* includes provisions to manage international vessels suspected to be harbouring NIMS. However, these provisions are non specific for biofouling pests and are not actively being used to manage the risk posed by biofouling on vessels. The *Offshore Petroleum and Greenhouse Gas Storage Act 2006* also has provisions for managing environmental issues relating to petroleum industry activities. However, the development and administration of environment plans that are required under the Act is administered by the respective state and territory jurisdictions.

All states and territories have legislation, predominantly fisheries acts and regulations that can be used to protect their coastal waters against the arrival of NIMS. Appendix C provides a summary of current jurisdictional legislative powers and the manner and degree to which they are applied to marine pest management.

WA currently enforces the most stringent requirements for biofouling management. Four Acts and specific Ministerial conditions allow the state to intervene when vessels enter WA. Vessels that are operating on particular offshore projects are required to manage for biofouling risks through their Environmental Management Plans. As a result, Australian based petroleum producers have opted to develop and apply NIMS risk assessment procedures, also endorsed by the WA Department of Fisheries. WA is also working with the Australian Government to develop a state-wide Marine Biosecurity Compliance Plan that is consistent with the proposed Commonwealth regulatory requirements.

The NT government introduced a vessel inspection protocol in 1999 providing for assessment, inspection and treatment prior to issuing a clearance certification. The protocol applies to recreational vessels entering NT marinas. Any vessel that has travelled in international waters and that is unable to demonstrate that the hull has been cleaned or antifouled in Australia is requested to undergo a hull inspection and treatment of internal seawater systems to kill marine pests. The NT Government covers the costs associated with hull inspections and treating the internal seawater systems of the vessels. There are currently no formally communicated operational policies for the inspection of other vessel types.

The remaining states and territories all have the legislative powers to protect and manage biofouling risk yet the extent to which these are enforced is minimal. In previous years, most jurisdictions have been required to act in response to an event, yet they have not outlined any specific policy measures to prevent the risk of an event occurring. This has resulted in the identification of NIMS being discovered by chance through other mechanisms rather than through a targeted risk management approach.

Data are unavailable to measure the effectiveness of the current approach compared with a scenario of no regulation but at the least, it can be concluded that the approach would be improved and the risks would be more likely to be reduced if the approach was better coordinated and targeted across all jurisdictions.

3.4 National voluntary guidelines

In 2009, a series of guidelines for biofouling management were released through the joint initiative of the Australian and state and territory governments – in conjunction with maritime industries – the National System. The National System was developed as Australia's response to the threat posed by marine pests with the objective of providing a nationally coordinated and consistent approach. Five sets of guidelines were released for recreational vessels, commercial fishing vessels, commercial vessels, non-trading vessels and for the petroleum production and exploration industry.

The guidelines were designed to assist industry to manage its own biofouling risks. They provide practical advice on how to minimise the risk of spreading marine pests including through regular inspection, cleaning of vessels and gear and application of anti-fouling coatings. Uptake of the guidelines is voluntary. They were designed to assist industry to manage its own biofouling risks.

Section 3.7 outlines how industry has adopted the guidelines in some cases as a strategy to meet requirements of the WA Department of Fisheries. However, there is limited evidence of widespread uptake of the guidelines.

3.5 International biofouling management

In 2007 the International Maritime Organisation (IMO) Marine Environment Protection Committee (MEPC) recognised the risks associated with biofouling as significant and added consideration of managing this risk to its work program. Since then, Australia has been actively involved in work to develop voluntary international *Guidelines to minimise the transfer of invasive aquatic species by ships' biofouling*. In July 2011, MEPC approved the guidelines. This means IMO member states can now begin to implement the guidelines.

The IMO guidelines provide guidance on minimising biofouling niches in new vessel builds, modifications to existing vessels to minimise biofouling accumulation, the use and application of antifouling paints, risk assessment and conduct of in-water cleaning activities as well as the keeping of records. The guidance is consistent with Australia's national guidelines and the options proposed within this RIS to manage biofouling risks.

The IMO process has resulted in increased global awareness of the risks associated with biofouling issue. Other member states, including the USA (specifically California) and New Zealand are developing domestic biofouling regulatory management measures. California plans to implement regulations from 1 January 2012, specifically to manage biofouling on commercial vessels. Both New Zealand and California's approaches differ from the proposed Australian Government approach. Australia's proposed approach is to manage for particular biofouling pest species, whereas New Zealand and California seek to manage for a level of fouling. Both measures are ultimately working towards achieving behaviour change in relation to improved vessel cleaning and maintenance which reduces the risks associated with biofouling.

Potentially, international activity will have some consequences for Australia although voluntary guidelines alone are not expected to have a significant impact. Further, analysis of vessel movements shows that most vessels entering Australian waters are from the North West Pacific followed by East Asian Seas and the South Pacific. Unless regulatory regimes are imposed in these locations, particularly in East Asia, risks to the Australian marine environment are unlikely to be substantially mitigated.

Although, the international guidelines are voluntary, it is possible to foresee them being replaced with more formal arrangements, such as a treaty, in future. If Australia were to commit to more formal arrangements then, regardless of its own priorities, it would be obliged to implement measures consistent with any international agreement.

3.6 Industry biofouling management

A number of companies and industry bodies whose members operate in Australian waters have developed and implemented biofouling mitigation action. This has primarily occurred in WA in response to WA Department of Fisheries hull-fouling interventions, or to address vessel efficiency or public perceptions.

Some examples of industry initiatives that have been promoted to industry, by industry, include:

- Implementation of the National System biofouling management guidelines
- Industry codes of environmental practice that consider and manage risk posed by non-indigenous marine species
- Company specific NIMS risk assessment procedures
- Development of company specific biofouling management plans and record keeping documents
- Implementation of NIMS inspections prior to vessels departing for Australia
- Development and implementation of maintenance schedules that deliberately consider fouling issues
- Project specifications that require fouling to be considered and managed throughout the term of a vessel's contract.

3.7 Conclusions on the effectiveness of the current arrangements

The current arrangements for managing the establishment of NIMS in Australia do not provide a consistent or comprehensive approach to managing biofouling risks. All Australian states and territories have legislation that enables government authorities to protect their coastal waters from NIMS, yet the extent to which these are applied is limited. For most jurisdictions, the detection and identification of NIMS is by chance, through other compliance mechanisms rather than undertaking a targeted risk management approach specific to biofouling risks.

Extensive research has been undertaken on how NIMS are introduced and the risks they present, yet most jurisdictions lack operating procedures outlining which vessels will be targeted, how vessel risks are assessed, and in some cases, which species are of most concern and why. Consequently, inconsistencies between the content and degree of application of this jurisdictional legislation render the current jurisdiction-based biofouling management strategy largely ineffective at the national level.

Voluntary national guidelines have existed since 2009 and international guidelines were approved through the IMO in 2011. There are currently no measures of the effectiveness of these voluntary guidelines. However, it is not anticipated they will significantly reduce the risk unless there is some incentive for vessel operators to take them up. Some companies have adopted them in WA where more stringent regulations are applied.

On this basis, there is clear evidence to suggest that, under the current arrangements, risks associated with the establishment of NIMS are not being effectively managed, and there is a rational basis for considering alternative approaches to managing these risks.

3.8 Rationale for government intervention

Government action can be justified where market failures exist. In relation to biofouling, these could take the form of:

- Externalities – Where the costs of biofouling are not fully captured in the market.
- Information asymmetries – Where one party in a transaction has a greater amount or better quality information than the other, which may disadvantage the other.

3.8.1 Externalities

Hewitt and Campbell (2010) identified that marine vessel movements are the greatest contributor to the translocation of NIMS. Despite this, the negative impacts are shared by all marine users and broader society.[3]

These costs are currently not factored into the decisions of vessel owners to mitigate biofouling risks. That is, their decisions on vessel treatments or maintenance are not influenced by these shared costs. The market alone is therefore unlikely to act to minimise these costs, in the absence of any direct action by governments to 'internalise' these costs.

3.8.2 Information asymmetries

Information asymmetries are relevant in two important areas.

First, vessel owners will often have more information about their actions or the condition of their vessel than the owners of ports which they enter. This information, such as type and quality of anti-fouling paints, time in a port, and the last time the vessel was treated or inspected, would all be useful in determining the extent to which a vessel presents a biofouling risk.

There is little incentive for vessel owners to provide this information, particularly for those who may be aware that they are high risk. Further, the presence of NIMS is not readily observable without an inspection (that is, it is not possible to identify a vessel with a NIMS from a cursory observation alone). It is unlikely that all vessel owners will provide sufficient information to allow for management of biofouling risks without some means of requiring them to.

Second, there may be a small proportion of vessel owners who are not aware of the risks associated with biofouling and therefore may not consider acting to reduce risks. Further these owners may not be aware of the value of information on risks, and therefore would not provide this information unless prompted to do so. This unawareness may arise because:

- some businesses lack the technical knowledge and expertise to interpret available information on the risks

- the cost (in terms of time and effort) to access information on these risks may be prohibitive for some businesses, particularly small-to-medium enterprises who may not have the resources to source it.

In some cases, the introduction and domestic translocation of NIMS may not be deliberate because those contributing to the situation may not be aware of the negative costs generated by their actions. Lack of understanding and acceptance of responsibility for NIMS introduction and management could contribute to the associated costs being under-valued.

These market failures establish a basis for considering whether government action is appropriate.

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[3] Refer to Appendix E on non-use values for a broader discussion on impacts to broader community.

4 Objectives of government action

The objective of government action is to minimise the negative impacts associated with NIMS being introduced into Australia through biofouling (with a focus on those NIMS that are SOC). These negative impacts include impacts on:

- maritime industries and associated sectors
- communities that rely on the marine environment for recreation and amenity
- the overall health of the marine environment, including biodiversity, which has flow-on impacts on the broader community in non-use values of the environment.

5 Statement of options

The following sections outline two options to be assessed in this RIS, as to whether they are likely to achieve the objectives set out in chapter 4. These are:

- **Option 1:** introduce regulations to manage the risks of NIMS establishing associated with biofouling – These regulations would impose time restrictions on high and extreme risk vessels and would sometimes require other actions if these vessels wish to stay in or return to Australian waters

- **Option 2:** implement an education program to encourage improved voluntary biofouling management.

A base case is also described. Establishing the base case provides the basis for analysing the costs and benefits of each of the options. This analysis is presented in chapter 6.

5.1 Base case

The base case represents the likely future scenario should neither of the options be implemented. It is not static and takes into account expected future policy developments, both at a Commonwealth level and at the State and Territory level.

For this RIS, the base case is captured by the following scenario:

- No new legislation or regulation at the Commonwealth level to address biofouling risks through a national approach

- No new action to address biofouling risks by States that currently do not have any communicated strategy in place to address biofouling risks (New South Wales, Victoria, QLD, Tasmania and South Australia)

- The NT would review its existing legislative reach and extend it to include other types of vessels (not just recreational) that it could then intervene on and inspect for SOC

- WA would develop a management strategy to address biofouling risks through a risk-based inspection of vessels

- The Australian Government would disseminate the IMO *Guidelines to minimise the transfer of invasive aquatic species by ships' biofouling* to state and territory government agencies and to key maritime industry groups such as those representing ports, shipping, petroleum production and exploration, shipwrights, recreational vessels and paint companies. Although the IMO guidelines would be available on the Department's website and the Australian Government would refer to the guidelines when responding to biofouling inquiries, additional communication and implementation activities would be unlikely.

5.2 Option 1 – Regulatory approach to biofouling management

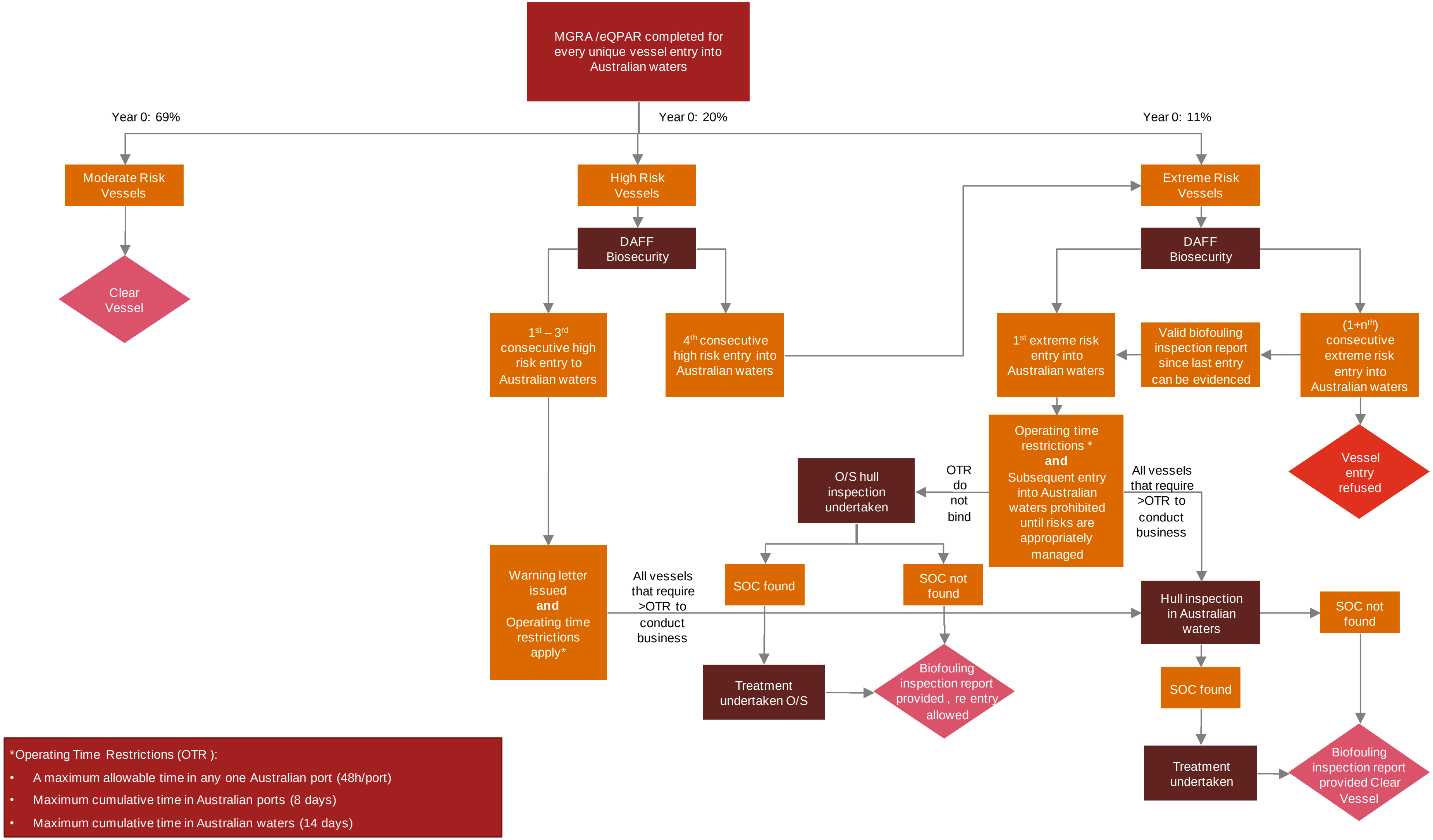
Option 1 is the implementation of new biofouling regulations by the Australian Government.

The intention of the new regulations would be to reduce the risk of the introduction and spread of NIMS associated with biofouling, by providing a risk-based, transparent, nationally consistent and enforceable management strategy. The strategy for all vessels other than yachts is illustrated in Figure 1. The strategy for yachts is shown in Figure 2.

Under this option, all vessels entering Australian waters would be required to have their biofouling risk level assessed through an online tool. Those that present as higher than moderate risk will be subject to certain restrictions and requirements upon entry to Australia.

The following sections describe the regulatory approach in more detail, including assumptions that have been made about the operation and effectiveness of the approach in order to analyse the costs and benefits.

Figure 1: Operational Strategy for Biofouling Management Regulations – All vessels excluding Yachts



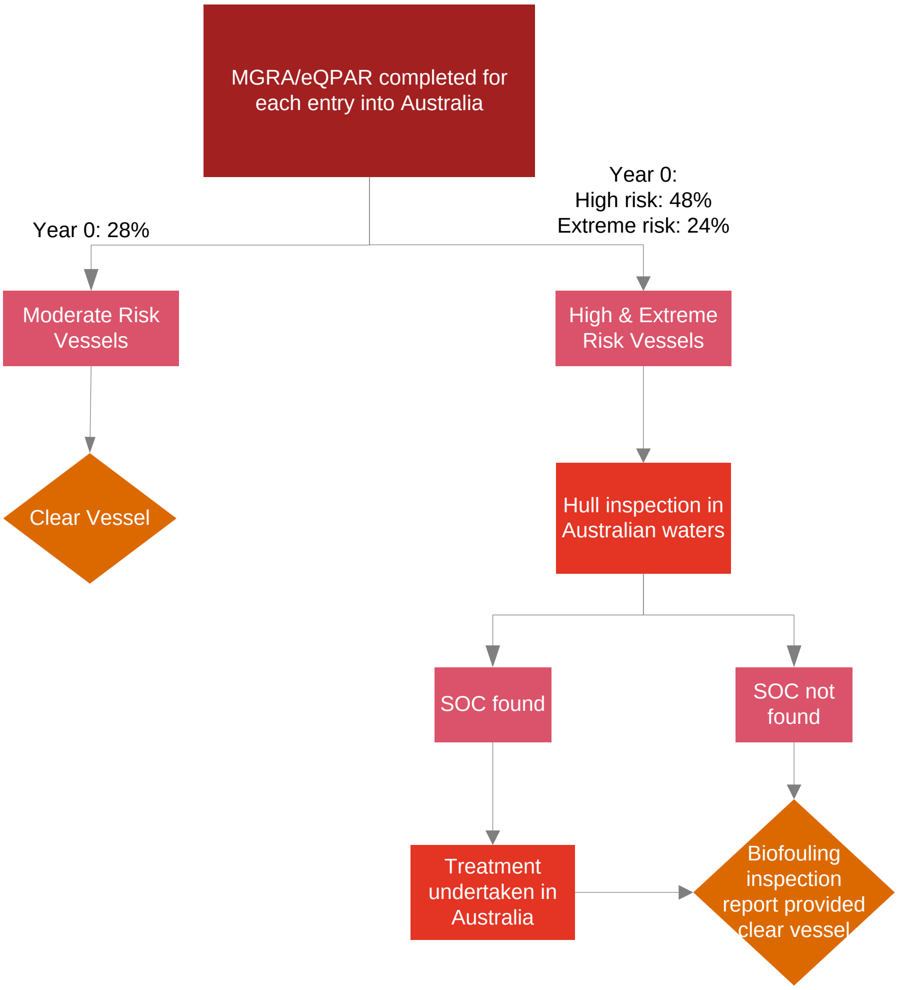
*Operating Time Restrictions (OTR):

- A maximum allowable time in any one Australian port (48h/port)
- Maximum cumulative time in Australian ports (8 days)
- Maximum cumulative time in Australian waters (14 days)

Source: Department of Agriculture, Fisheries and Forestry

Note: This diagram applies to all vessels other than yachts. The Department recognises that this operational strategy will need to be tailored to suit the unique requirements of the petroleum industry and seeks comments during the consultation process on the approach that is under development with the petroleum industry. It is assumed that the changes will not be significant and are therefore unlikely to significantly affect the estimated costs to the petroleum industry.

Figure 2: Operational Strategy for Biofouling Management Regulations – Yachts



Source: Department Agriculture, Fisheries and Forestry

5.2.1 *Identification of risk*

The Australian Government has developed a tool—the Marine Growth Risk Assessment (MGRA)—to assess the risk an individual vessel presents for carrying biofouling associated NIMS. The MGRA comprises a series of questions about:

- presence and age of antifouling coating
- presence and operation of internal seawater treatment systems
- evidence of recent hull surveys or inspections that have considered marine growth
- duration of stay in overseas ports
- anticipated time in Australian waters.

Based on answers to each of the questions, an estimate of the risk that a vessel is harbouring NIMS is calculated. Risk categories are defined as Moderate, High and Extreme. The MGRA would be examined by a Biosecurity Officer during an interview process.

It is proposed that the MGRA be available to vessel operators online and as part of the electronic Quarantine Pre Arrival Report (eQPAR), which vessels currently submit for quarantine purposes. This will allow vessel operators to self-assess their vessels prior to departure for Australian waters and consider undergoing pre arrival biofouling management activities at their discretion. Activities may include cleaning submerged surfaces, reducing time in international ports, or applying anti-fouling coatings.

The MGRA tool was piloted during 2010 by representatives of maritime industries, regional Seaports officers and state/NT governments. Based on the data collected during the pilot, the majority of general vessels fell within the moderate risk category (69 per cent). Of the remaining vessels, 20 per cent were categorised as high risk and 11 per cent as extreme risk.[4] For yachts, 24 per cent were estimated to be extreme risk, 48 per cent high risk and 28 per cent moderate risk.

5.2.2 Implications of risk profile

Under the proposed regulations, the actions undertaken when a vessel enters Australian waters would depend on the vessel's MGRA risk category. The actions that could be undertaken for each category are outlined in this section.

Moderate risk (Vessels excluding yachts):

If a vessel is considered to be moderate risk then no further action is required. Vessels within this category may be allowed to enter Australian waters without time restrictions. A small number of vessels will be inspected for verification and audit purposes. Auditing is likely to identify a proportion of vessels that should be categorised as high or extreme risk. A policy on this auditing and verification process will be developed.

High risk (Vessels excluding yachts):

Vessels assessed as high risk will be subject to interview by DAFF Biosecurity. A DAFF Biosecurity interview involves a biosecurity officer boarding a vessel, inspecting documents to verify answers provided within the MGRA, and considering other factors such as on-board biofouling management processes. Following the interview, the vessel will be allowed to enter Australian waters with the provision of a warning letter and the application of operating time restrictions (OTR). The OTR under this option are:

- a maximum allowable time in any one Australian port of 48 hours
- a maximum cumulative time in Australian ports of 8 days
- a maximum cumulative time in Australian waters of 14 days.

If a vessel is unable to conduct its business within these OTR it must either leave Australian waters or be subject to a hull inspection in Australian waters (eg dive inspection or alternative underwater inspection method). If a hull inspection is undertaken, one of the following outcomes will result:

- **A SOC is not identified** – In this case the inspector will provide the biosecurity officer with documentation declaring the vessel free from quarantinable pests. The vessel is free to continue its activities within Australian waters for that voyage
- **A SOC is identified** – In this case the infected vessel must undertake biofouling treatment, and is not allowed to resume conducting its business within Australian waters until this has occurred.

If a vessel is classified as 'high risk' for four consecutive entries into Australia, on the fourth high risk assessment it will automatically be classified as an 'extreme risk' entry.

Extreme risk (Vessels excluding yachts)

Vessels falling into the extreme risk category for the first time would be subject to interview by DAFF Biosecurity and the defined OTR. If a vessel is unable to conduct its business within the OTR, it is subject to the same process of inspection and treatment (where required), as those vessels in the high risk category.

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[4] Slight adjustments to the MGRA results were made to normalise the results. Refer to Appendix D for further details.

If the vessel is able to conduct its business within the OTR it may continue its current voyage, but subsequent entry into Australian waters is prohibited until a hull inspection is undertaken, along with treatment if a SOC is found.

Vessels classified as extreme risk for two (or more) consecutive entries into Australian waters will be refused entry on the second (or subsequent) occasion. The exception is if a valid biofouling inspection report can be produced for the vessel declaring it free from quarantinable pests which has been obtained since its last extreme risk entry. In this case the vessel will be treated as if it is its first extreme risk entry.

Yachts

The implications of risk classification are less complex for yachts. If a yacht is assessed as a moderate risk no further action is required. If a yacht is classified as high or extreme risk then it would be subject to a hull inspection in Australian waters. If no SOC is found during inspection, the yacht is free to continue regular activities within Australian waters. If a SOC is identified, treatment will be undertaken and the yacht can continue regular activities once it is declared free of quarantinable pests.

Consultation question

Do the proposed operating time restrictions on high and extreme risk vessels achieve an appropriate balance between minimising biological risk (which increases with time) and minimising the impact on vessel operators (who may need more time)? If not, why and what would be a better balance?

5.3 Option 2 – Education program to encourage voluntary biofouling management

Option 2 involves a targeted education program to promote voluntary adoption of a biofouling management regime and is outlined below.

5.3.1 Proposed approach

An education program will be developed targeting the owners, operators and agents of vessels arriving from international waters. The program will raise awareness of the threat of marine pests affecting the Australian marine environment and encourage owners and operators of vessels to adopt recommended practices that are set out in the national guidance documents. Owners and operators will also be encouraged to assess and if necessary, mitigate the biofouling risk, prior to arrival of the vessel in Australia.

The education program will be tailored to cater for the information needs of each sector (commercial vessels, non trading vessels, petroleum production and exploration vessels, commercial fishing vessels and recreation vessels), and will include:

- building strategic relationships with key sector representatives, both within Australia and overseas
- development of sector specific implementation plans, including the identification of existing communication channels with each sector and design and production of supporting communication materials
- rolling out the education program within each sector over a six-year time frame. This timeframe is based on the minimum time required to measure the potential benefits as well as ensuring the education program captures a broad range of stakeholders
- making information materials publically available via the Department's website, the marine pest website, www.marinepests.gov.au, and relevant industry websites.

Information would be would be provided to industry sectors through the following channels:[5]

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[5] NB: All documents originally developed for the 2005 voluntary guidelines will be revised to ensure consistent and up-to-date terms for the revised voluntary option.

- disseminated to all vessels prior to and on arrival at their first port of call in Australia
- made publically available via the Department's and state/territory Government websites, shipping agents and industry bodies and at www.marinepests.gov.au
- National Biofouling Management Guidelines for individual sectors will be available at www.marinepests.gov.au
- sector specific implementation plans.

The education program would be consistent with the IMO Guidelines and would seek to include international stakeholders such as the IMO and International Federation of Shipping in the engagement process to broaden communication avenues.

6 Impact analysis

This chapter provides a summary of the assessment of the costs and benefits of implementing the regulatory and voluntary options described in chapter 5. More detailed analysis and explanation of methodology (including modelling assumptions) is provided in Appendix D.

6.1 Assumptions for the base case

The base case for this RIS assumes no additional intervention or incentive schemes would be implemented by the Australian Government to manage the risks associated with vessel biofouling. The Australian Government would disseminate the IMO guidelines to each jurisdiction and key industry groups as well as make them publicly available on the Department's website.

To estimate the costs and benefits for options 1 and 2, assumptions also need to be made about the potential future actions of governments in WA and the NT. Recent discussions with states and territories suggest that, while there is a strong preference for a national approach to managing risks (through regulation or other means), WA may consider introducing its own state-based scheme and the NT would consider extending the reach of its legislation to intervene on a broader range of vessels rather than just recreational vessels.

There are many uncertainties about the nature, timing and scale of any approach that would be implemented by these jurisdictions.

Proposed regulatory impacts could be implemented at less cost (with proportionally, less benefit) at the Commonwealth level if vessels operating in WA and NT had to comply with state-based requirements that are comparable to those considered in option 1.

Conversely, proposed regulatory impacts might be implemented at higher cost (with proportionally higher benefits) if vessels operating in WA and NT had to comply with state-based requirements which differ from those being considered in option 1. That is, the higher end estimates reflect an assumption that any actions in WA and NT would have no impact on the costs or benefits discussed under option 1.

Costs and benefits have been calculated for both scenarios. However, it is also possible that the approach in NT and WA result in costs and benefits that fall somewhere in between these lower and higher and estimates.

The proportion of vessels affected by WA and NT government actions is estimated to be 35 per cent based on analysis of vessel movement data.

For simplicity and given the uncertainty, it is assumed that there is no lag in these jurisdictions actions and that their approaches would commence from year one of implementation of either option 1 or 2. The cost estimates provide a reasonable upper and lower limit of the impact of actions in these jurisdictions but does not reflect the full range of possibilities given the unpredictability of future actions in each jurisdiction.

Possible impacts of these jurisdictions actions on the estimated benefits are also discussed in the following sections.

6.2 Option 1 – Regulatory approach to biofouling management

This section provides a summary of estimates of the costs and benefits of implementing a national biofouling regulatory approach compared with the base case.

6.2.1 Assumptions about change in behaviour due to regulations

The purpose of the regulatory option is to identify those vessels that present risks to Australia (in terms of introduction of a SOC), and require actions by vessel owners to mitigate these risks. These actions impose a range of costs on vessel owners and operators, which are discussed and estimated in section 6.2.2. The presence of these costs – both financial and opportunity costs – suggests that over time operators should act to avoid costs where they are able. For instance, given the additional costs that the regulations impose on vessel operators in the high and extreme categories, it is anticipated that the proportion of vessels within these categories will decrease over time. Increased awareness and incorporation of biofouling management practices into regular maintenance regimes is expected to occur. This will lead to a corresponding increase in the proportion of moderate risk vessels as more vessels that were high or extreme risk become moderate.

The highest cost implications are for those vessels categorised as extreme risk and which attempt to make consecutive entries without a valid biofouling inspection report. These vessels will not be permitted to enter Australian waters. The cost implications for yachts are less severe than other vessels and the assumptions have been moderated accordingly.

It has been assumed that in years 1 to 3 there will be a 50 per cent net annual decrease in the proportion of extreme risk vessels entering Australian waters (15 per cent for yachts) and a 10 per cent net annual decrease in the proportion of high risk vessels (4 per cent for yachts). In year 4, it is anticipated that a new equilibrium level of compliance will be reached and the relative proportions within the risk categories will remain constant from year 4 into the future. These assumptions have been sensitivity tested (see section 6.4).

Consultation question

How might vessel operators' behaviour change in response to the proposed regulations?

6.2.2 Costs

The costs likely to be incurred from implementation of the new biofouling regulations are direct costs incurred by marine vessel operators and flow-on costs to the Australian economy. The latter have not been considered in this analysis due to difficulties deriving accurate estimates. However, they could be significant. For example they could affect vessel sailing itineraries, and use of Australian treatment facilities with flow on impacts for related businesses and services.

The expected costs to vessel operators have been organised into four cost categories:

1. Cost of completing the hazard identification tool (MGRA)
2. DAFF Biosecurity interview costs
3. Vessel inspection costs
4. Vessel treatment costs.

There are two elements essential to calculating the costs in each category. These are:

1. Calculating the expected number of vessels that will incur a particular cost. This will depend on the number of vessels entering Australia, the overall risk profile of these vessels, the number of vessels unable to operate within the defined OTR, the number of vessels that undertake biofouling management actions as a result of the regulations, and the probability that a vessel is infected with a SOC.
2. Calculating the cost of a particular item for different vessel types. The magnitude and type of cost incurred will differ due to different vessel characteristics. For example, large vessels will require more time to undertake treatment than smaller vessels, hence the opportunity cost of treatment will be higher.

Cost of completing the hazard identification tool (MGRA)

Under this option, it is proposed that before entering Australia all vessel operators would be required to complete the MGRA electronically. As the MGRA is to be included in the eQPAR, which vessels currently must submit for quarantine purposes, it is assumed that there will be negligible additional costs to vessel operators in filling out the additional questions in the eQPAR. No MGRA completion costs have been incorporated into the cost benefit analysis model for this option.

DAFF Biosecurity interview costs

All vessels that are identified as being in the high or extreme risk categories (based on their MGRA response) would be subject to DAFF Biosecurity interview. The time required for this interview is not expected to be significant, and the associated opportunity costs for the vessel operators are assumed to be minor, and are therefore not included in the cost estimates.

The Department has advised that current interview costs for general vessels, regardless of type, are $90 per vessel entry, based on 30 minutes of compliance time. This cost would be passed on to vessel operators. Interview costs for yachts are not considered because they are already asked a number of biofouling questions upon arrival and this is incorporated into the current fee structure.

The total costs for all vessel entries into Australia can be estimated by applying the $90 interview costs per vessel entry of relevant vessels.

Vessel inspection costs

Under the proposed regulations, a proportion of vessels may be required to undergo a hull inspection within Australia, or they may choose to undertake an inspection overseas. Which of these occurs in practice is influenced by the business decisions of vessel owners. Those vessels in the high or extreme risk categories that require a longer period than the imposed OTR to conduct business in Australia would be subject to a hull inspection in Australia (as they are not able to comply with the OTR, they must be inspected while in Australian waters).Those vessels in the extreme risk category that are not subject to OTR are assumed to undertake inspections overseas (that is, they would leave immediately and have an inspection overseas before entering Australian again). It is also assumed that all vessels in the consecutive extreme risk entry category that are refused entry into Australia, will undertake an inspection overseas in order to be able to enter Australian waters in future. Figure 2 shows that all yachts in the extreme and high risk categories will be subject to inspection in Australia.

The cost of an inspection is assumed to be the same whether undertaken in Australia or overseas, and is not expected to vary significantly with vessel length. With the exception of mobile offshore drilling units and yachts, the average inspection cost per vessel is estimated by the Department to be $12,000. Higher inspection costs are incurred by mobile offshore drilling units due to their complexity ($50,000) and yachts incur lower inspection costs ($180) as they are smaller and simpler in design and physical inspections can be readily carried out.

Additionally, it is assumed that the regulations would lead to some operators changing their behaviour (by undertaking additional biofouling management activities before entering Australia) in order to lower their potential to be categorised as high or extreme risk when they enter Australian waters. Although these activities are undertaken of the operators' own accord, the estimated costs of these activities are included in this RIS as they would not be incurred if the regulations were not in place. It is expected that vessels would undertake biofouling management activities in this manner if the cost of doing so was less than the cost of unplanned management of biofouling.

Most commercial vessel operators are expected to be able to incorporate biofouling inspections into their regular maintenance and hull classification survey regime. On average, vessels are required to undertake 5 yearly, intermediate (2.5 year) and annual hull classification surveys. The additional cost of incorporating a biofouling inspection in this regime is estimated to be less than an inspection for the sole purpose of biofouling. The Department has estimated biofouling inspection costs for this group of vessels as $6,000 per vessel ($25,000 in the case of mobile offshore drilling units). Inspection costs for yachts in this group are expected to remain at $180 due to there being no change in the nature of the inspection carried out.

By applying these inspection costs per vessel entry to the number of vessels expected to incur the costs, the total costs for all vessel entries into Australia can be estimated.

Vessel treatment costs

As illustrated in Figure 1, if a SOC is found on a vessel during an inspection, the vessel is required to undergo biofouling treatment if inspected in Australia, and is assumed to undergo treatment if inspected overseas.

For this analysis, each vessel risk category (moderate, high, and extreme) is assumed to have a different probability of carrying a SOC. Anecdotal feedback of inspectors to the Department suggests that up to 20 per cent of extreme risk vessels could harbour a SOC. Based on this information, assumptions have then been made to estimate the likelihood of vessels carrying a SOC as:

- 20 per cent for extreme risk vessels
- 5 per cent for high risk vessels
- 0.1 per cent for moderate risk vessels.

Again, these estimates are subject to considerable uncertainty and the impacts of adjusting them on estimating the costs are sensitivity tested in section 6.4.

To calculate the number of vessels that incur treatment costs, these percentages are applied to the number of vessels in each risk category that are assumed to undergo inspection.

The cost of treatment for a particular vessel depends upon:

- The type of treatment undertaken – vessels may be treated in water or out of water (OOW)
- The opportunity cost of the number of days it takes to complete the treatment
- The opportunity cost of any travel time required to travel to a treatment facility.

A number of assumptions in regards to treatment costs and treatment decisions have been made. These are set out in Appendix D.

By applying the relevant treatment costs to the number of vessels expected to incur the costs, the total costs for all vessel entries into Australia can be estimated.

Costs to government

The costs identified above relate to vessel operators. These include some of the costs of the Government's administration of the regulations since vessel operations will be charged for services provide by Government including the costs of interviews conducted by DAFF Biosecurity officers. However, there are some costs that will be incurred by Government that are not recovered. These include developing and drafting the regulations and roll-out and maintenance of the MGRA. These costs are core government business and have not been included in the cost benefit analysis.

Summary of expected costs

The total costs of implementing the new regulations are presented in Table 1 below. As outlined in section 6.1 these two estimates to account for the possible action of WA and NT to develop their own state based regulations. The net present value (NPV) of costs over a period of 10 years is presented. These calculations are often made over a longer period, say 30 years. However, given the amount of uncertainty about the assumptions used and recognising that this uncertainty increases with the projection of the costs over a long time frame, a period of 10 years is used in this case. A longer timeframe is more critical where the costs include significant up-front capital costs, which is not the case for the proposed regulatory approach.

An annual discount rate of 7 per cent has been applied to all cash flows. The table shows that the total cost of option 1 is estimated at between $132.7 and $204.1 million in NPV terms. This is predominantly driven by inspection costs– for inspections undertaken either within or outside of Australia, which represent 52 per cent of the total costs of the option.

Table 1: Summary of costs directly attributed to Commonwealth regulations

Cost item	NPV ($M2011, FY11) No comparable regulations in WA & NT	NPV ($M2011, FY11) Comparable regulations in WA & NT	Percentage of total costs
Inspection/Interview costs			
DAFF Biosecurity interview costs	$1.3M	$0.8M	1%
Additional pre-planned inspection costs	$9.5M	$6.2M	5%
Inspection costs (DAFF Biosecurity directed)	$95.3M	$62.0M	47%
Total Inspection/Interview Costs	$106.1M	$69.0M	53%
Treatment costs			
In water treatment	$36.8M	$23.9M	18%
In water treatment time	$5.9M	$3.8M	3%
OOW treatment	$39.0M	$25.4M	19%
OOW treatment time	$2.1M	$1.4M	1%
Travel in Australia	$4.2M	$2.8M	2%
Travel from Australia to O/S	$10.0M	$6.5M	5%
Total Treatment Costs	$98.0M	$63.7M	47%
Total Cost	**$204.1M**	**$132.7M**	**100%**

Questions for consultation

What specific types of flow-on costs and benefits to the Australian economy of the proposed might be significant?

The estimates of costs are based on average vessel numbers from 2002-2009. Is there any activity or trends that suggest any significant change in vessel movement or increased numbers of arrivals?

Are the cost assumptions consistent with industry experience? (see Appendix D for all assumptions). Are there better estimates of costs available?

Are the other assumptions used to estimate costs and benefits reasonable based on industry experience? If not, how could they be improved?

6.2.3 Benefits

The potential benefit of the regulatory approach to biofouling management is essentially the value of any reduced impact from biofouling (where it leads to the establishment of a SOC).

The economic benefits from the avoidance of damage caused by SOC establishing in Australia is difficult to estimate, as the extent of potential damage that could be caused is not known with a high degree of certainty. The analysis in this section uses the best available information to estimate the potential positive impact of a reduction in biofouling risks. The estimates are dependent on assumptions on the extent of change in behaviour and the impact this has on reducing the likelihood of a SOC becoming established.

Effectiveness of regulatory approach in reducing SOC establishment

The effectiveness of the regulatory approach in reducing the number of vessels entering Australia harbouring a SOC depends on a number of factors including:

- the number of vessel entries in each risk category under the MGRA;
- the probability of a vessel in each risk category harbouring a SOC;
- the number of vessels in each risk category that are inspected under the regulations; and
- the resulting number of vessels in each risk category harbouring a SOC that are likely to remain in Australian waters with the regulations in place.

Table 2 provides a summary of the estimated number of vessels entering Australia harbouring a SOC before the implementation of the regulations (year 0) and after the regulations are implemented in years 1, 2, 3, and 4 onwards given the assumptions that have been made about changes in behaviour to mitigate risk.

Under the status quo, it is estimated that 3.5 per cent of vessels enter Australian waters harbouring a SOC each year. With implementation of the regulations this is estimated that is can be reduced to 0.51 per cent in the first year, 0.47 per cent in the second year and 0.43 per cent per a year thereafter.

Table 2: Number of vessels entering Australia harbouring a SOC

Year	# Moderate risk vessels	# High risk vessels	# Extreme risk vessels	Total # of vessels	% of all vessels entering that harbour a SOC
Year 0 (before implementation of regulations)	8	136	295	439	3.5%
Year 1	9	54	0	63	0.51%
Year 2	10	49	0	58	0.47%
Year 3	10	44	0	54	0.43%
Year 4 on	10	44	0	54	0.43%

Note: Totals may not sum due to rounding.

The likelihood of new species arriving in Australia and subsequently establishing is outlined in section 3.1 of this RIS. The establishment rate outlined in this section was used to calculate the expected number of SOC to arrive in Australian waters in each of the next ten years. The cumulative number of SOC expected to arrive under the status quo (base case) was calculated as 8.3 in the case of WA and NT implementing biofouling management regulations that do not affect international vessels, and 3.3 in the case that WA and NT implement regulations similar to those proposed under this option. The cumulative number of SOC expected to arrive under the new regulations is 1.8.

Potential avoided costs

There have been a number of Australian and international cases where invasions of SOC have had documented impacts. Key examples with estimated economic costs are detailed in Table 3.

Table 3: Examples of global incursions of SOC and their impacts

Species	Location	Impacts	Economic costs
Asian Clam (Corbicula fluminea)	USA	• Clogs industrial water intake pipes • Outcompetes native species.	US$1 billion per year in damages and control costs (Invasive Species Specialist Group (ISSG), 2005)
Chinese mitten crab *(Eriocheir sinensis*)	Germany	• Burrowing activity damages dykes and increases river embankment erosion • Preys on commercially important species • Outcompetes native species • Clogs water intake filters • Destroys commercial shellfish beds and preys on native oysters and crabs.	€80 million in Germany since 1912 (Gollashch, 2006a)
European zebra mussel (*Dreissena polymorpha*)	USA, Canada	• Alters food webs and outcompetes native species • Fouls vessel hulls, marine structures and navigational buoys • Clogs industrial water intake and outlet pipes (Cohen, 1998).	US$600 million per year (Canyon *et al*., 2002)
Raphidophyte (Chattonella antiqua)	Japan	• Significant damage to fisheries.	US$30 million damage to cultured yellowtail between 1972 – 1989 (Nakamura *et a*l., 1989)
Black striped mussel (*Mytilopsis sallei*)	Australia	• Alters food webs and outcompetes native species • Fouls vessel hulls, marine structures and navigational buoys • Clogs industrial water intake and outlet pipes.	A$2 million in eradication costs Threatened $40 million Australian Pearl Industry (Bax *et al*., 2002)

As the examples in Table 3 illustrate, the impact of SOC establishments globally have been highly variable. The worst documented case appears to be the establishment of the Asian Clam in the USA, estimated to cost US$1 billion every year. However, there are cases where the cost has been significantly less, for example, Raphidophyte in Japan is estimated to have caused less than US$2 million per annum damage to the cultured yellowtail fishing industry.

In South Australia (SA) it is estimated the total costs to date to manage the marine alga *Caulerpa taxifolia* since 2002 to be approximately $11 million (Department of Primary Industries and Resources of SA, pers com, 2011).

The avoided costs also depend on the response once a species is established. For example, up front eradication costs could be incurred and if eradication is successful, no additional costs would be incurred. Alternatively, if eradication is not successful, there could be ongoing costs.

The level of potential damage that could be caused by any particular one of the 56 SOC not yet in Australia is not known.

Estimating benefits based on the economic value at risk

One approach is to estimate the total economic value at risk from SOC establishing. Benefits could then be estimated based on the effectiveness of the regulatory approach in protecting the value at risk.

The major industries reliant upon the marine resources that might be damaged as a result of biofouling are the commercial fishing industry and the maritime tourism and recreation industry. A severe impact scenario has been modelled that assumes the establishment of SOC will:

- put around 40 percent of the value added component of the entire Australian commercial fishing industry at risk
- reduce the number of trips to one quarter of the Great Barrier Reef (GBR) by 58 per cent because of the impacts of a SOC on that part of the reef.

The rationale for these assumptions is provided in Appendix D. Historically, there are no cases where an individual NIMS or multiple NIMS are known to have caused this level of economic damage in Australia. Modelling this scenario does, however, help to establish an upper bound for the possible avoided economic costs that result from improved management of the risk of SOC becoming established. Given uncertainties and known impacts of some species overseas, it is also possible that certain species not yet established in Australia could have widespread adverse impacts of this order of magnitude.

For example, the comb jellyfish appeared in the Black Sea in 1982. The population of jellyfish grew rapidly and profoundly modified the ecosystem. The anchovy catch fell from 204,000 tons in 1984 to 200 tons in 1993, sprat from 24,600 tons in 1984 to 12,000 tons in 1993 and horse mackerel from 4,000 tons in 1984 to zero in 1993 (Meinesz, 2003). The economic impacts for the Black Sea are estimated to be in the hundreds of millions of dollars (Shiganaova and Panov, 2006).

The calculation of the total quantifiable benefits using this ‘total value at risk’ method is dependent upon:

- the economic value at risk from a SOC entering and establishing in Australia of
  - the marine tourism and recreation industry
  - the commercial fishing industry.
- the difference between the number of SOC to establish in Australia annually under the base case and under the new regulations.

Table 4 below shows calculated values for the total benefits attributed to the value at risk from each industry calculated over an appraisal period of 10 years, discounted at 7% per annum.

Table 4: Summary of benefits directly attributed to Commonwealth regulations

Benefit category ($M)	PV ($M2011, FY11) No comparable regulations in WA & NT	PV ($M2011, FY11) Comparable regulations in WA & NT	Percentage of total benefit (PV)
Value at risk without regulations			
Commercial fishing	$160.4M	$121.3M	
Marine tourism and recreation	$250.1M	$189.2M	
Total value at risk without regulations	**$410.5M**	**$310.5M**	
Value at risk with regulations			
Commercial fishing	$48.7M	$48.7M	
Marine tourism and recreation	$76.0M	$76.0M	
Total value at risk with regulations	**$124.7M**	**$124.7M**	

Benefit category ($M)	PV ($M2011, FY11) No comparable regulations in WA & NT	PV ($M2011, FY11) Comparable regulations in WA & NT	Percentage of total benefit (PV)
Total benefit from regulations			
Commercial fishing	$111.7M	$72.6M	39%
Marine tourism and recreation	$174.2M	$113.2M	61%
Total Benefits	**$285.9M**	**$185.8M**	**100%**

Table 4 shows that the base case value at risk that is directly attributable to Commonwealth regulations is lower when WA and NT introduce a regulatory regime similar to the proposed regulations.

Question for consultation

The methodology for estimating the economic value at risk relies on a series of assumptions (set out in Appendix D) about the value of commercial fishing and the Great Barrier Reef. Are there more plausible assumptions or approaches that could be used?

6.2.4 Non-use benefits associated with reducing environmental impacts from biofouling

'Non-use' benefits are the benefits associated with the value that society places on maintaining a particular asset, such as a heritage building, artefact or location with significant environmental importance. These benefits are termed as 'non-use' because they are not derived from consuming services from the asset (such as visiting a heritage site, or participating in recreation activities in a region). Non-use values are essentially the benefits society derives from the understanding that an item or area of importance is protected.

There are three key types of non-use benefits that are recognised in economic literature:

- **Existence value —** Many users hold existence values for environmental resources in that they may not ever make use of the resource but enjoy the satisfaction of simply knowing it exists. The desire to preserve the environmental resource exists regardless of any current or expected future use. [6]

- **Option value —** Refers to users who may not intend to use the environmental resource at this point in time, yet wish to have the option of accessing the resource should they wish to change their mind. For example, some users may not wish to visit a national park at the moment but will want to have the option to visit in the future.

- **Bequest value —** Placing value on the fact that future generations will be able to access an environmental resource, in the same state and quality as current generations is known as bequest value.

There are a number of different methods used by researchers to estimate non-use benefits. These are primarily survey methods which seek to gather information about an individual's preferences to protect particular assets or environmental regions, through measures such as 'willingness to pay' or consumer surplus. The table below provides a summary of the most relevant, and recent studies on non-use benefits related to marine environments (primarily in Australia). The methods used for valuation of non-use benefits are typically focused on a specific region and use proxies to estimate values, such as considering the value of having the region available for access, value to individuals of maintaining particular characteristics of the environment such as coral, fish species and other species. This research has been used to measure the extent to which individuals may value measures by governments to protect these environments, such as the introduction of marine protection areas.

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[6] Crowards, T (1995) Nonuse Values and Economic Valuation of the Environment: A Review, CSERFE Working Paper GEC 95-26, University of East Anglia and University College London.

Table 5: Summary of Recent Economic Studies on non-use benefits from marine environments

Approach to estimating values	Results[7]
Travel Cost Method and Contingent Behaviour Model	A study was undertaken on the GBR to investigate the responsiveness of recreational fishing demand to changes in costs and other factors such as catch rates and environmental conditions. All changes measured comprised of less than 10 per cent of total consumer surplus. Decreasing catch rates by 25 per cent results in a decrease of $110,992 while an increase by 50 per cent results in an increase of $487,417.
Contingent Behaviour Approach	A contingent behaviour survey was conducted on the GBR to estimate the recreational demand for reef trips following a hypothetical decline in reef quality, through a reduction in fish and coral biodiversity. Consumer surplus of current reef visitors who pursue diving or snorkelling trips is approximately $185 per trip. Following a hypothetical decrease in coral and fish biodiversity, demand could decrease by up to 80 per cent. A decrease of this size is estimated to reduce reef trip expenditure on commercial vessels by up to $200 million per year.
Choice Modelling Technique	A choice modelling technique was used to measure non-use values for protecting the environmental health of the Fitzroy estuary in central Queensland. Value for the health of the Fitzroy estuary averages $3.21 per household for a one per cent improvement in the health of the estuary. Extrapolating this assumption to a state level produces an approximate value of $647,100. If current trends continue 65 per cent will be in good condition in 20 years time.
Travel Cost Method and Contingent Valuation Method	A study was undertaken to estimate the economic value of Rawapening in Indonesia by incorporating both a Travel Cost Method and Contingent Valuation Method. Rawapening is a major source of ecotourism for Indonesia and possesses similar biodiversity risks to the Australian ecosystem. Value of consumer surplus in Rawapening was Rp 7,410 billion whilst the overall value of benefits per year amounted to Rp 1,654 billion.
Choice Modelling Approach	A choice modelling approach was used to value the ecological attributes for the Ningaloo Marine Park and the proposed Ngari Capes Marine Park in WA. Willingness to pay for Ningaloo and Ngari Capes Marine Parks was $51 per year and $46 per year respectively, for a 5 per cent increase in fish populations. Indicative value for a package of ecological improvements provides a willingness to pay value of $139 per year. Aggregated value approximates to $222 million per annum.

For the purpose of this RIS, the potential benefits of the options under consideration are the improved protection of marine environments where the options are effective in reducing the rate of establishment of SOC. Where the rate of establishment diminishes, so do the risks of damage to marine environments. There is currently no available robust estimate of the non-use value of Australia's marine environment at an *aggregate* level — That is, something that would estimate the total value rather than focusing on particular regions. For these reasons, the estimates of non-use values have not been aggregated.

That is not to say that these impacts should not be considered. The relevant research provides the following conclusions:

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[7] A detailed explanation of all references is provided in Appendix E.

- There is strong evidence that consumers place a positive value on the existence of particular iconic marine regions in Australia, such as coral reef areas
- The overall health of marine areas, not just the iconic regions is important for many people and they would be willing to fund protection of these regions.

These findings suggest that there is a positive benefit associated with protection of particular regions. For instance, the value placed on the Ningaloo reef for WA residents alone is estimated to be $222 million. A marginal reduction in the risks associated with NIMS for all marine regions in Australia is likely to be many times this magnitude. Analysis in this RIS suggests that the regulatory approach will be effective in reducing the establishment of SOC. Further, it is clear that, aside from the benefits related to the economic value at risk of marine industries, there are additional non-use benefits. This analysis supports the conclusion that the there are significant potential benefits from reducing biofouling risks.

6.2.5 Broader benefits from improved biofouling management

There is a range of other potential avoided costs that we have not attempted to quantify in the analysis because of the difficulty in obtaining data. These are outlined below.

Protecting human health

An assessment of marine pest risks associated with biofouling commissioned by the Department included assessment of human health, defined as the value of a safe and healthy society shared equally across generations and socio-economic groups (Hewitt *et al.*, 2011a).

Many of the hundreds of species that were assessed were found to present a moderate to extreme risk to human health. However, within the final list of high risk species, 11 pose a moderate, high, or extreme risk to human health. Some pose a moderate to extreme risk through human consumption because of their demonstrated ability to bioaccumulate toxins in sufficient quantities to cause human illness (MacQuarrie and Bricelj, 2008; Hewitt *et al.*, 2011a; Oikawa *et al.*, 2004; Tanu and Noguchi, 1999).

One is an intermittent host of the oriental lung fluke, which carries a high risk of being transferred to humans potentially resulting in acute or chronic illness (Gollasch, 2006a). Another was determined to present a high risk to human health because it is a carrier of a parasite that causes septicaemia in patients with weakened immune systems (Garnier *et al.*, 2007, Nappier *et al.*, 2010). Further, some species presented high risk of laceration if introduced into recreational marine and coastal areas (Hewitt *et al.*, 2011a).

Social and cultural benefits

Social and cultural benefits relate to values of a location in relation to human use for pleasure and aesthetic purposes as well as inter-generational values. This value category also takes into account iconic or spiritual value, including locations that create a sense of local, regional or national identity.

Seven sub-components of social value associated with the use of costal and marine ecosystems have been identified, each with various social, cultural and spiritual activities associated with them. These include potential impacts on human health, restricted trade and port beaches (as a proxy for a number of land-based activities); surfing; diving; boating (yachting; cruising, kayaking etc.); seafood gathering (Shellfish gathering and recreational fishing); iconic landscapes; and archaeological use (MAF Biosecurity New Zealand, 2009).

Examples of marine pests that detrimentally affect social values include:

- *Eriocheir sinensis* which is a major nuisance to anglers taking a variety of baits including ghost shrimp and shad (Hewitt *et al.*, 2011a)
- *Ulva* species produce noxious odours which prevent people from using recreational areas
- *Didemnum vexillum, Dreissena polymorpha, Mytilopsis sallei* and *Perna* species have the potential to cause loss of aesthetic value to a region, including loss of recreational value.

It can be difficult to articulate some aspects of social value because they are, to a large extent, intangible. Many activities associated with coastal areas have an economic value as well as social value (for example, purchase of supplies, accommodation, and maintenance of equipment).

Reduced likelihood of a quarantine area being declared

If a quarantine area is declared, resulting in a harbour being closed down for a period of time, it restricts vessel movements to and from the harbour. The recent closures of Cairns harbour in 2001 and early 2008 highlighted the potential impact these could have on the fishing industry. The closure happened to coincide with the start of the prawning season and a large number of vessels associated with the Northern Trawl Fishery were in port at the time. There was a limited window of opportunity to commence fishing operations and this was almost missed due to the closure of the harbour. The value of catch in Cairns was much lower than in unaffected locations such as Mooloolabah and Eden.

The probability of such events occurring is extremely low as these typically would only occur at the start of the season or when vessels return to the harbour during the season.

Increase vessel fuel efficiency

One of the positive effects of vessels undertaking additional biofouling treatment is the likely beneficial impact on fuel efficiency.

Biofouling decreases the overall efficiency of marine vessels. The increased vessel weight and surface roughness causes increased frictional resistance of the vessel within water thereby increasing fuel costs and decreasing vessel speed (Schultz *et al.,* 2011, Townsin, 2003).

A study of US Navy Arleigh Burke-class destroyers showed that primary biofouling (heavy slime) of submerged surfaces resulted in 1.4 per cent decrease in fuel efficiently. Secondary and tertiary biofouling caused a greater than 20 per cent decrease in fuel efficiency (Schultz, *et al*., 2011).

While there is potential for improved fuel efficiency resulting from the regulations, many commercial vessels are already likely to be managing any biofouling that significantly affects their fuel efficiency. Nevertheless, it is possible that there is an additional positive side effect. It is difficult to quantify the magnitude of the benefit.

6.2.6 Summary of quantified impacts of option 1

Table 6 below presents the quantified costs and benefits as well as the total net benefits of Option 1. The NPV is calculated using a discount rate of 7 per cent a year over a ten year appraisal period.

Table 6: Summary of costs and benefits directly attributed to Commonwealth regulations (option 1)

Cost/Benefit Item	NPV ($M2011, FY11) No comparable regulations in WA & NT	NPV ($M2011, FY11) Comparable regulations in WA & NT	Percentage of PV costs/benefits
Costs			
Inspection/Interview Costs			
DAFF Biosecurity interview costs	$1.3M	$0.8M	1%
Additional pre-planned inspection costs	$9.5M	$6.2M	5%
Inspection costs (Unplanned)	$95.3M	$62.0M	47%
Total Inspection/Interview Costs	**$106.1M**	**$69.0M**	53%

Cost/Benefit Item	NPV ($M2011, FY11) No comparable regulations in WA & NT	NPV ($M2011, FY11) Comparable regulations in WA & NT	Percentage of PV costs/benefits
Treatment Costs			
In water treatment	$36.8M	$23.9M	18%
In water treatment time	$5.9M	$3.8M	3%
OOW treatment	$39.0M	$25.4M	19%
OOW treatment time	$2.1M	$1.4M	1%
Travel in Australia	$4.2M	$2.8M	2%
Travel from Australia to O/S	$10.0M	$6.5M	5%
Total Treatment Costs	**$98.0M**	**$63.7M**	47%
Total Costs	**$204.1M**	**$132.7M**	**100%**
Benefits			
Commercial fishing	$111.7M	$72.6M	39%
Marine tourism and recreation	$174.2M	$113.2M	61%
Total Benefits	**$285.9M**	**$185.8M**	**100%**
Net impact			
Total Net Benefits	**81.8M**	**53.2M**	
Benefit Cost Ratio	**1.4**	**1.4**	
Non-use Benefits	**Evidence suggest highly positive for a number of marine regions**		

The table illustrates that option 1 provides total net benefits of $81.8 million in net present value terms, in the case that WA and NT only implement biofouling management regulations that do not duplicate the effect of the Australian Government's regulations eg by only targeting domestic vessels, and net benefits of $53.2 million in the case that WA and NT implement regulations that are consistent with those proposed in option 1.

The benefit to cost ratio (BCR) in both cases is 1.4. As outlined in section 6.2 quantifying the benefits is challenging using available data and only one approach has been modelled based on the estimated value at risk of fisheries and marine tourism. The modelled value is a high end estimate of the impacts on these industries but does not include other benefits that have not been quantified including, health, environmental, impacts on port facilities and non-use values.

6.3 Option 2 – Education program to encourage voluntary biofouling management

The costs and benefits of option 2 have also been analysed. Some costs are borne by government which would fund the program. Some costs will also be voluntarily incurred by vessel operators assuming the education program has some effect in changing behaviour. The types of benefits are the same as for option 1 but there is an assumption that the total quantum will be much less since the education program is not expected to result in the same level of behavioural change as option 1.

6.3.1 Costs

The costs associated with Option 2 are primarily costs to government of developing and implementing the education program for stakeholders as well as the inspection and treatment costs voluntarily incurred by a proportion of the industry.

Because industry is not required to implement any regulatory requirements, Option 2 assumes that the rate of behavioural change occurs at only 10 percent of the rate it occurs under option 1. Further, not all of the same types of costs would be incurred. For example, no DAFF Biosecurity interview costs would be incurred. Costs that could be voluntarily incurred include:

- additional pre-planned inspection costs
- additional in water treatment costs
- additional out of water treatment costs.

Government will also incur costs associated with developing the education program, engaging with and disseminating the information to industry, and addressing industry questions on the content of the guidelines. Specifically, government will be required to:

- build strategic relationships with key sector representatives
- coordinate and development sector-specific communication strategies and tools
- implement the sector-specific programs.

Government cost estimates have been based on the costs associated with a communication program for the commercial fishing industry. This included a one off cost of approximately $200,000 for development of the communication strategy, and for design and production of the supporting communication materials and tools; and approximately $70,000 (excluding staff costs) for delivery of the program over two years from 2009 to 2011. These costs have been multiplied by six to account for six distinct industry sectors that would be targeted by the program.

The communications program on which these costs are based was designed for a domestic industry for which there was no peak representative body and for which the delivery mechanism was a one–on–one approach to fishermen at wharves by industry based extension officers. For the international maritime sectors targeted in this education program, the communication approach will need to be adjusted to account for the industry structure and existing communication channels within the sector, and for some of the targeted decision makers being based off-shore.

Based on the financial schedule of the communication project for the commercial fishing industry, and assuming that similar costs apply to each of the 5 targeted sectors, the total costs associated with the development and implementation of the education program over 6 years would be $2.3 million.

Table 7: Summary of costs directly attributed to Commonwealth educational program (option 2)

Cost Item	NPV ($M2011, FY11) No comparable regulations in WA & NT	NPV ($M2011, FY11) Comparable regulations in WA & NT
Costs to Government		
Establishment costs	$1.2M	$1.2M
Roll-out costs	$0.4M	$0.4M
Staff costs	$0.7M	$0.7M
Total Cost to Government	**$2.3M**	**$2.3M**
Cost to Industry		
Costs to vessel operators	$3.2M	$2.1 M
Total Cost to Industry	$3.2M	$2.1 M
Total Cost	**$5.4M**	**$4.4M**

6.3.2 *Benefits*

The scope of potential benefits of this option is similar to option 1. For this option, however, only a proportion of the effectiveness of the regulatory option has been assumed. This proportion has been based on the assumption that the reduction in the number of SOC entering Australia is likely to be less effective than the regulatory option. This assumption is made on the basis that:

- The education program is information based, and therefore relies solely on the value of information to change behaviour
- The guidelines are expected to be adopted by industries for which a biofouling management plan is beneficial – Eg to increase vessel efficiency, to assist in compliance with the IMO Guidelines, or to improve public perceptions through increased environmental awareness
- The audience that would be best placed to act on the information is difficult to identify and target with an information approach, as for some sectors, they are based overseas
- The information would not be supported with a broader approach to inspect or check vessels, aside from the relatively small number of checks already being conducted. This limits the extent to which the approach will be able to pick up vessels with a potential SOC, which may occur even when a vessel owner is well informed.

The following sections provide estimates of the quantified benefits for this option given the assumptions on the rate of behaviour change for the voluntary option. As for option 1, the only modelled benefits are based on a high end estimate based on the value at risk of the fisheries and marine tourism industries.

Table 8: Summary of benefits directly attributed to Commonwealth educational program (option 2)

Benefit category ($M)	PV ($M2011, FY11) No comparable regulations in WA & NT	PV ($M2011, FY11) Comparable regulations in WA & NT	Percentage of total benefit (PV)
Value at risk without voluntary guidelines			
Commercial fishing	$160.4M	$121.3M	
Marine tourism and recreation	$250.1M	$189.2M	
Total Value at risk without voluntary guidelines	**$410.5M**	**$310.5M**	
Value at risk with voluntary guidelines			
Commercial fishing	$150.8	$115.1	
Marine tourism and recreation	$235.2	$179.4	
Total Value at risk with voluntary guidelines	**$386.0M**	**$282.0M**	
Total Benefit from voluntary option			
Commercial fishing	$9.6M	$6.2M	39%
Marine tourism and recreation	$15.0M	$9.8M	61%
Total Benefits	**$24.6M**	**$16.0M**	**100%**

Question for consultation

What is industry's view of the likely effectiveness of a voluntary approach to reducing the risks associated with biofouling compared to a regulatory approach?

Effectiveness of voluntary approach in reducing SOC establishment

The effectiveness of the voluntary approach in reducing the number of vessels entering Australia harbouring a SOC depends on the same factors as outlined for option 1.

Table 9 provides a summary of the number of vessels entering Australia harbouring a SOC before the implementation of the regulations (year 0) and after the regulations are implemented in years 1, 2, 3, and 4 onwards.

Under the status quo, 3.5 per cent of vessels enter Australian waters harbouring a SOC each year, whereas with implementation of the regulations and based on the assumptions made, this is predicted to be reduced to 3.4 per cent in the first year, 3.3 per cent in the second year and 3.2 per cent per annum thereafter.

Table 9: Number of vessels entering Australia harbouring a SOC (voluntary option)

Year	# Moderate risk vessels	# High risk vessels	# Extreme risk vessels	Total # of vessels	% of all vessels entering that harbour a SOC
Year 0 (before implementation of regulations)	8	136	295	439	3.5%
Year 1	8	133	268	409	3.4%
Year 2	9	132	256	396	3.3%
Year 3	9	131	244	383	3.2%
Year 4 on	9	132	256	397	3.2%

Note: Totals may not sum due to rounding.

The cumulative number of SOC expected to arrive under the status quo (base case) was calculated as 8.29, and the number under the voluntary option is expected to be 7.68.

6.3.3 Summary of costs and benefits of Option 2

The net impact of Option 2 is a net benefit of between $11.6 million and $19.2 million. This result is driven by assumptions around the level of behavioural change. The benefit to cost ratio is significantly higher for this option at between 3.6 and 4.5 than option 1. However, the total benefits are much less reflecting that the risk from biofouling would not be reduced to the same extent as a regulatory option.

Table 10: Summary of costs and benefits directly attributable to Commonwealth educational program (option 2)

Cost/Benefit item	PV ($2011M, FY11) No comparable regulations in WA & NT	PV ($2011M, FY11) Comparable regulations in WA & NT
Costs		
Voluntary Guidelines		
Establishment costs	$1.2M	$1.2M
Rollout costs	$0.4M	$0.4M
Department FTE’s	$0.7M	$0.7M
Costs to vessel operators	$3.2M	$2.1 M
Total Costs	**$5.4M**	**$4.4M**
Benefits		
Commercial fishing	$9.6M	$6.2M
Marine tourism and recreation	$15.0M	$9.8M
Total Benefits	**$24.6M**	**$16.0M**
Net impact		
Total Net Benefit	**$19.2M**	**$11.6M**
BCR	**4.5**	**3.6**

6.4 *Sensitivity analysis*

The variables chosen to be included in the sensitivity analysis are those for which there was limited information on which to base an assumption including:

- vessel charter rates
- the economic value at risk of the commercial fisheries and tourism industries
- the assumed rates of infection for vessels in the moderate, high and extreme categories
- the assumed rates of behavioural change for the first three years for vessel operators categorised in the high and extreme risk categories.

To account for the variation in base case and for completeness, the base case scenario that assumes comparable regulation in WA and NT is in place is displayed as a sensitivity test. If sensitivity of the other variables was tested against this case, the same relative movements in BCRs would be observed as for the case in which comparable regulations are not in place in these jurisdictions.

Table 11: Values for sensitivity analysis Option 1

Sensitivity test #	Assumption	Value in base case	Sensitivity low	Sensitivity high
1	Comparable regulations in WA & NT (no. of vessels affected)	100%	65%	-
2 and 3	Charter rates	x (varies by vessel type	0.5x	1.5x
4	Economic value at risk (tourism and fisheries)	x	0.5x	-
5	Infection rates: high	5%	-	10%
5	Infection rates: moderate	0.1%	-	2.0%
6. Low case 7. High case	Vessel reduction in extreme category per year yrs 1 – 3	50%	30%	70%
6. Low case 7. High case	Vessel reduction in high category per year yrs 1 – 3	10%	0%	20%

Table 12: Results of Sensitivity Analysis Option 1

	Base case	Sensitivity case						
Benefit ($M2011, FY11)	**No comparable regulation in WA & NT**	**1.Comparable regulation in WA & NT**	**2. Charter rates +50%**	**3. Charter rates -50%**	**4. Economic value at risk -50%**	**5. Infection rate moderate=2% High=10%**	**6.Change in vessel owner behaviour – low case**	**7. Change in vessel owner behaviour – high case**
Costs								
Inspection/Interview costs	$106.2M	$69.0M	$106.2M	$106.2M	$106.2M	$106.2M	$148.8M	$77.2M
Treatment costs	$98.0M	$63.7M	$109.0M	$86.9M	$98.0M	$129.2M	$146.4M	$66.4M
Total Costs	**$204.1M**	**$132.7**	**$215.1M**	**$193.1M**	**$204.1M**	**$235.4M**	**$295.3M**	**$143.6M**

	Base case	Sensitivity case						
Benefit ($M2011, FY11)	No comparable regulation in WA & NT	1.Comparable regulation in WA & NT	2. Charter rates +50%	3. Charter rates -50%	4. Economic value at risk -50%	5. Infection rate moderate=2% High=10%	6.Change in vessel owner behaviour – low case	7. Change in vessel owner behaviour – high case
Benefits								
Commercial fishing	$111.7M	$72.6M	$111.7M	$111.7M	$55.8M	$76.2M	$107.9M	$114.9M
Marine tourism and recreation	$174.2M	$113.2M	$174.2M	$174.2M	$87.1M	$118.8M	$168.3M	$179.2M
Non-use benefits	Evidence suggests highly positive for a number of marine regions							
Total Benefits	**$285.9M**	**$185.8**	**$285.9M**	**$285.9M**	**$142.9M**	**$195.0M**	**$276.2M**	**$294.0M**
Net impact								
NPV	**$81.8M**	**$53.1**	**$70.7M**	**$92.8M**	**-$61.2M**	**-$40.3M**	**-$19.1M**	**$150.4M**
BCR	**1.4**	**1.4**	**1.3**	**1.5**	**0.7**	**0.8**	**0.9**	**2.1**

The sensitivity testing illustrates that the factor with the greatest influence on the results is the estimated economic value at risk to industry caused by biofouling. When the value at risk is halved, the regulatory option’s costs outweigh the benefits by approximately $60 million and the BCR falls to 0.7, indicating that in this case the costs outweigh the benefits.

The estimated rate of infection for vessels also has a material influence on the effectiveness of option 1. If it vessels in the moderate risk category have a 2 per cent chance of harbouring a SOC and high risk vessels have a 10 per cent chance, this increases the costs of the option, as treatment costs for vessels increase. The benefits also fall in this case, as additional vessels in the moderate risk category will enter Australia harbouring a SOC (moderate category vessels are not inspected), thereby reducing the effectiveness of the regulations.

The change estimated to occur in vessel owner behaviour due to implementation of the regulations also significantly influences the outcome calculated for option 1. If there is a low response from vessel owners to the regulations, overall costs increase due to an increase in DAFF Biosecurity directed inspection and treatment costs. Benefits also fall, as the regulations are not as effective as in the central case. This causes the resulting NPV to be negative and the BCR of the option to fall below 1. Conversely, a high response from vessel owners reduces the costs of the option, and increases the effectiveness of the regulations, resulting in an NPV of $150 million and a BCR of 2.1

A 50 per cent change in the charter rates in either direction does not have a material effect on the NPV or BCR of the regulatory option.

In summary, the economic value at risk, the estimated rate of infection, and the estimated response of vessel owners to the regulations will all have a material effect on the cost benefit analysis results for option 1.

The results of the sensitivity analysis for option 2 show that the assumed rate of behavioural change does not have a significant impact on the results for option 2. In both the low case and high case, the NPV remains positive and the BCR above 1.

Table 13: Values for sensitivity analysis of Option 2

Sensitivity test #	Assumption	Value in central case	Sensitivity low	Sensitivity high
1.	Comparable regulations in WA & NT (no. of vessels affected)	100%	65%	-
2. Low Case 3. High Case	Vessel reduction in extreme and high categories per year yrs 1-3	10% of regulatory option	5% of voluntary option	20% of voluntary option

Table 14: Results of Sensitivity analysis of Option 2

	Sensitivity case			
Benefit ($M2011, FY11)	**Base case** **No comparable regulation in WA & NT**	**1. Comparable regulation in WA & NT**	**2. Change in vessel owner behaviour – low case**	**3. Change in vessel owner behaviour – high case**
Costs				
Establishment costs	$1.2M	$1.2M	$1.2M	$1.2M
Roll–out costs	$0.4M	$0.4M	$0.4M	$0.4M
Staff costs	$0.7M	$0.7M	$0.7M	$0.7M
Costs to vessel operators	$3.2M	$2.1M	$1.6M	$6.1M
Total Costs	**$5.4M**	**$4.4M**	**$3.9M**	**$8.3M**
Benefits				
Commercial fishing	$9.6M	$6.2M	$5.1M	$18.2M
Marine tourism and recreation	$15.0M	$9.8M	$7.9M	$28.3M
Total Benefits	**$24.6M**	**$16.0M**	**$13.0M**	**$46.5M**
Net impact				
NPV	**$19.2M**	**$11.6M**	**$9.2M**	**$38.1M**
BCR	**4.5**	**3.6**	**3.4**	**5.6**

7 Findings and recommendation

The intent of government action in relation to biofouling is to manage risk rather than a known quantity or impact. The analysis suggests that regulation will mitigate the risk to a much greater extent than the voluntary option but this comes at a much higher cost. These costs could be outweighed by the benefits given the possible range of benefits that have been identified but this is not certain.

The relatively low costs of option 2, the education program, means that any small change in behaviour as a result of the program is likely to generate benefits that outweigh the costs but the overall risk is unlikely to be reduced to a great extent.

Despite the limitations of the analysis, option 1, the regulatory option, is recommended subject to the outcomes of public consultation. This is because it is more likely to substantively contribute to reducing the risk of NIMS establishing in Australia’s marine environment than the education program.

A further consideration is international developments. Now that international guidelines have been approved, global awareness of the risks of biofouling has increased. Some other jurisdictions, including California and New Zealand are planning to introduce regulations. It is also foreseeable, but by no means certain, that an international treaty could be developed. This international activity may create additional incentive for Australia to implement a regulatory regime consistent with international guidelines. Option 1 has intentionally been developed to be consistent with the international guidelines.

8 Consultation

The Steering Committee now seeks input from stakeholders on this RIS. The RIS is subject to a 90 day consultation period and the Steering Committee welcomes feedback on the analysis and findings in this document.

During development of alternative options for the management of biofouling risks, the Department consulted with various stakeholders including:

- Apache Corporation
- Australian Government Department of Sustainability, Environment, Water, Population and Communities
- Australian Petroleum, Production and Exploration Association
- Australian Shipowners Association
- Biofouling Solutions Pty Ltd
- Biosecurity Queensland, Department of Employment, Economic Development and Innovation
- Biosecurity South Australia, Department of Primary Industries and Resources South Australia
- BHP Billiton Limited
- Californian State Lands Commission
- Chevron Corporation
- ConocoPhilips Company
- Crawford School of Economics and Government, Australian National University
- INPEX Corporation
- Minerals Council of Australia
- National Bulk Commodities Group Inc.
- National Introduced Marine Pests Coordination Group (superseded by the Marine Pest Sectoral Committee).
- New South Wales Department of Primary Industries
- Biosecurity New Zealand, New Zealand Government Ministry of Agriculture and Forestry
- Northern Territory Department of Resources
- Ports Australia
- Shipping Australia Limited
- University of Central Queensland

- University of Tasmania
- URS Australia
- Victoria Department of Sustainability and Environment
- Woodside Petroleum Limited
- Western Australia Department of Fisheries.

9 Implementation and review

A timeline and key steps for implementation and review of government action will be developed following public consultation on this RIS and a final decision on the preferred option.

If the regulatory approach is adopted, it is anticipated the regulations would commence during late 2012/early 2013.

Ongoing monitoring of any reforms will be undertaken by the Department to ensure that the objectives are being achieved and whether any further reforms are necessary.

Appendices

Appendix A Research on NIMS introduction and impacts

NIMS incursions in Australia

A number of Australian cases exist where invasions by NIMS have had documented impacts. The following examples provide the most detailed information on impacts associated with the introduction of a NIMS.

Asian green mussel (Perna viridis)

Detected on a moored vessel located in Trinity Inlet, Cairns where it was subsequently removed (Hayes *et al.*, 2005).

Commonly found in sea-chests of vessels, particularly those that have travelled in the South-East Asia region (Coutts and Dodgshun 2007).

A nuisance biofouling species that quickly populates and fouls submerged surfaces including wharves, jetties, boats, mariculture equipment, navigation aids and water intakes of industrial cooling systems and desalination plants.

Presents an extreme-biofouling risk. It can accumulate toxins and viruses through filter feeding, and human consumption immediately following a toxic event can cause illness, and death (Ammons *et a*l., 2001; Lee *et al.*, 1997).

Black striped mussel (Mytilopsis sallei)

- It competes with native and commercial mollusc species for habitat and food; as well as causing economic and amenity damage to wharves, marinas, marine farms (NIMPIS, 2002), seawater systems (pumping stations, vessel ballast and cooling systems) and vessel hulls (Huang & Morton, 1983)
- Established and eradicated from three Darwin marinas in 1998.
    - Posed a significant threat to surrounding marine infrastructure, including the local $40 million pearl fishery industry (Bax, Hayer, Marshall, Parry, & Thresher, 2002)
    - The $2.2 million eradication campaign involved 250 people, 100 tons of chlorine and 10 tons of copper sulphate which were dumped into infested waters (Canyon, *et al.*, 2002)
    - One of only a handful of successful eradications of an established NIMS population in the world. Success was attributed to the early detection and the ability to isolate and treat the infected marinas.

European fan worm (Sabella spallanzanii)

- The European fan worm is a filter-feeding tube worm with the ability to rapidly proliferate, to physically alter native marine ecosystems and to outcompete with native and commercial species for food and habitat (MG & MJ, 2002).
- *Sabella spallanzanii* detrimentally affects aquaculture productivity, particularly the scallop, oysters and mussel industries (Claplin, *et al.*, 1995), and tourism industries that rely on marine biodiversity.
- First identified in Australian waters in 1965 and is now established in all Australian coastlines except Queensland and the Northern Territory (Canyon, *et al.*, 2002). It has no known predators in Australia (NIMPIS, 2011). Control and eradication of the European fan worm is not longer considered a feasible management option because an input of $800, 000 – $263 million would be required to manage the extensive geographical range it has invaded.

European green shore crab (Carcinus maenas).

- A small predatory crab with a demonstrable ability to out-compete native marine animals for food and habitat, by removing bivalves which filter algae and larvae (Waltona, MacKinnonb, Rodrigueza, Proctorb, & Ruiza, 2002; Grosholz et al., 2001).

- *Carcinus maen*as was identified on mainland Australia in the early 1900s (Fulton and Grant 1902). In the 1970's identified in New South Wales (Hutchings, van der Velde, & Keable, 1987) and South Australia (Zeidler, 1978) and during 1993 in Tasmania (Gardner, Paturusi, & Kwa, 1994).

- In North America, the European green shore crab causes an annual economic loss of approximately US$49 million (Lafferty and Kuris 1996). The impacts of this species in Australia has not been measured, but are expected to account for losses of up to $5 million within the commercial bivalve industry (Murray *et al.*, 2007; ABARE–BRS, 2009).

Japanese seaweed or Wakame (Undaria pinnatifida)

- *Undaria pinnatifida* was introduced to Tasmania in 1988 and has been spreading via natural dispersal at a rate of 5–10 kilometres per year since (Sanderson 1990; Sanderson 1997). Subsequently, range expansions of up to 50 kilometres have been reported, including establishment in several Victorian costal ecosystems. The domestic spread of this marine pest is attributed to the lack of sufficient control measures and domestic vessel movement (Sanderson 1997).

- *Undaria pinnatifida* continues to invade Australia's unique giant kelp forests in Tasmania, causing environmental and economic loses. In Italy and Argentina, the alga competes with indigenous seaweeds for space, resulting in reduced species richness and diversity of native seaweeds (Curiel *et al.*, 1998; Casas *et al.*, 2004). It has also been implicated in changes to the understorey composition in New Zealand waters (Forest and Taylor 2002).

NIMS associated with Biofouling by Location

There has been a range of research internationally focusing on estimating the linkage between establishment of NIMS and biofouling. The table below provides research estimates on this linkage.

Table 15: Percentage of NIMS that have been associated with vessel biofouling

Location	Percentage of non-indigenous marine species considered associated with biofouling	Reference
New Zealand	69%	Cranfield, *et al.*, 1998
Hawaii	74%	Eldredge & Carlton, 2002
North Sea	>50%	Gollasch, 2002
North America (USA)	70%	Fofonoff *et al.*, 2003
Port Phillip Bay, Australia	78%	Hewitt, *et al.*, 1999; Hewitt *et al.*, 2004
Australia (national port surveys)	59%–69%	Hewitt and Campbell 2010
Scotland	59%	(Ashton, Karin, Richard, & Elizabeth, 2006)
Japan	42%	Otani 2006

Location	**Percentage of non-indigenous marine species considered associated with biofouling**	**Reference**
Brazil	90%	Farrapeiraa C, In Press
Global (algae)	70%	Hewitt *et al.*, 2007
Global (all taxa)	55%	Hewitt and Campbell 2010

Source: Hewitt et al., (2011b).

Global incursions of NIMS

Table 16: Examples of global incursions of NIMS and their impacts

Species	**Location**	**Impacts**	**Economic costs**
Asian clam (Corbicula fluminea)	U.S.A	• Clogs industrial water intake pipes • Outcompetes native species.	US$1 billion in damages and control costs (Invasive Species Specialist Group (ISSG), 2005)
Chinese mitten crab *(Eriocheir sinensis)*	Germany	• Burrowing activity damages dykes and increases river embankment erosion. • Preys on commercially important species • Outcompetes native species • Clogs water intake filters • Destroys commercial shellfish beds and preys on native oysters and crabs.	€$80 million in Germany since 1912 (Gollash, 2006)
European zebra mussel *(Dreissena polymorpha)*	U.S.A; Canada	• Alters food webs and outcompetes native species • Fouls vessel hulls, marine structures and navigational buoys • Clogs industrial water intake and outlet pipes (Cohen, 1998).	US$600 million per year (Canyon, *et al.*, 2002)
Raphidophyte (Chattonella antiqua)	Japan	• Significant damage to fisheries.	US$30 million damage to cultured yellowtail between 1972-1989 (Nakamura, Takashima, & Watanabe, 1989)
Black striped mussel (Mytilopsis sallei)	Australia (exterminated)	• Alters food webs and outcompetes native species • Fouls vessel hulls, marine structures and navigational buoys • Clogs industrial water intake and outlet pipes.	A$2 million in eradication costs Threatened $40 million Australian Pearl Industry (Bax, *et al.*, 2002)

Appendix B Species of concern

Table 17 provides a summary of the 56 SOC that the Australian Government proposes to manage for under the proposed Australian Biofouling Management Requirements. Specific data for each of the species listed below that was used in analysis are provided in Appendix F of the Species Biofouling Risk Assessment which is available online at www.marinepests.gov.au. The Species Datasheets include: inoculation likelihood, biofouling association rank, transport pressure rank, physiological tolerances, potential impacts (environmental, economic, social/cultural, human health) and references.

Table 17: List of 56 species with risk rankings of extreme (E), high (H) or moderate (M) in at least one core value category and in at least one voyage duration from Hewitt, *et al.*, 2011c

Scientific name	Common name	Env risk	Econ risk	Social/ cultural risk	HH risk	Overall ranking	Overall risk
Charybdis japonica	Lady crab, Asian paddle crab	H	E		E	13	E
Sargassum muticum	Japanese seaweed, Japweed, wire weed, strangle weed	E	E	H		13	E
Eriocheir sinensis	Chinese mitten crab	H	H	H	H	12	E
Perna perna	Brown mussel, Mexilhao mussel	H	M	H	E	12	E
Perna viridis	Asian green mussel	H	M	H	E	12	E
Balanus improvisus	Bay barnacle, acorn barnacle	H	E		H	11	E
Didemnum vexillum	Colonial sea squirt	E	H	M		9	E
Mytilopsis sallei	Black striped mussel	H	E	M		9	E
Balanus eburneus	Ivory barnacle	E	M		H	9	E
Limnoperna fortunei	Golden mussel	H	H		H	9	E
Ulva pertusa	Sea lettuce	H	H	H		9	E
Crassostrea virginica	American oyster, Eastern oyster	H	H		H	9	E
Mytilopsis leucophaeta	Dark false mussel, Conrad's false mussel	H	E			8	E
Cliona thoosina	Boring sponge	H	H	M		7	E
Dreissena polymorpha	European zebra mussel	H	H	M		7	E
Crepidula fornicata	Slipper limpet, Atlantic slipper snail	H	H			6	E

Scientific name	Common name	Env risk	Econ risk	Social/ cultural risk	HH risk	Overall ranking	Overall risk
Rhithropanopeus harrisi	Harris mud crab, White-fingered mud crab, Zuiderzee crab	H	H			6	E
Hemigrapsus sanguineus	Asian shore crab, japanese shore crab	H	H			6	E
Brachidontes variabilis	Variable mussel	H	H			6	E
Crassostrea ariakensis	Suminoe oyster, Asian oyster	M	M		H	5	E
Dreissena bugensis	Quagga mussel	M	H	M		5	E
Solidobalanus fallax	Warm-water barnacle	H	M			4	H
Rapana venosa (R. thomasiana)	Rapa whelk	H	M			4	H
Corbicula fluminea	Asian clam, Asiatic clam	M	H			4	H
Sphaeroma annandalei	Isopod	H	M			4	H
Polydora nuchalis	Spionid polychaete worm		H			3	H
Callinectes sapidus	Blue crab		H			3	H
Carcinoscorpius rotundicauda	Mangrove horseshoe crab				H	3	H
Sylon hippolytes	Parasitic barnacle		H			3	H
Balanus glandula	Acorn barnacle	H				3	H
Chthamalus proteus	Atlantic barnacle, Caribbean barnacle	H				3	H
Briarosaccus callosus	Parasitic barnacle		H			3	H
Gmelinoides fasciatus	Baikalian amphipod	H				3	H
Anomia nobilis	Jingle shell, Saddle oyster	H				3	H
Bonamia ostreae	Haplosporidian parasite, Bonamia		H			3	H
Mytella charruana	Charru mussel	M	M			2	M
Loxothylacus panopaei	Sacculinid parasitic barnacle	M	M			2	M
Pseudochattonella farcimen	Raphidophyte	M	M			2	M
Chattonella antiqua	Raphidophyte	M	M			2	M
Anguillicola crassus	Parasitic nematode	M	M			2	M

Scientific name	Common name	Env risk	Econ risk	Social/ cultural risk	HH risk	Overall ranking	Overall risk
Anadara demiri	Arc shell	M	M			2	M
Avrainvillea amadelpha	Leather mudweed	M	M			2	M
Dikerogammarus villosus	Killer shrimp	M				1	M
Geukensia demissa	Ribbed mussel	M				1	M
Corethron criophilum	Diatom		M			1	M
Hydroides dianthus	Serpulid tube worm, limy tube worm		M			1	M
Acartia tonsa	Calanoid copepod	M				1	M
Ampelisca abdita	Amphipod (tube dwelling)	M				1	M
Crangonyx floridanus	Florida crangonyctid (amphipod)	M				1	M
Gammarus tigrinus	Amphipod	M				1	M
Pachygrapsus fakaravensis	Polynesian grapsid crab	M				1	M
Codium fragile atlanticum	Green sea fingers	M				1	M
Fucus evanescens	Brown algae	M				1	M
Gelliodes fibrosa	Grey encrusting sponge	M				1	M
Corbula (Potamocorbula) amurensis	Asian clam, Amur River clam, overbite clam, brackish-water corbula	M				1	M
Mya arenaria	Soft-shell clam, long-neck clam, steamer clam, sand gaper				M	1	M

Note: For the risk assessment M is associated the numerical value of 1, H is assigned to numerical value 3, E is assigned to numerical value 5 (Hewitt et al., 2010).

Some States and Territories currently have powers that enable them to control for biofouling species that are not currently present in Australia, which are not included in the list of 56 SOC (Table 17). These species include *Perna canaliculus, Hemigrapsus penicillatus and Ensis directus*.

- *P. canaliculus* was not included because it is not known to have successfully invaded and established itself anywhere in the world, despite the previous detection of several individuals in SA, which were successfully eradicated.
- *H. pencillatus* was not included due to lack of documented impacts due largely to relatively recent date of invasions resulting in risk rankings less than moderate for any individual core value.
- *E. directus* was not included due to limited global distribution and limited information on inferred or demonstrable impacts resulting in risk rankings less than moderate for any individual core value (Hewitt *et al.*, 2011c).

Appendix C Current legislation for managing marine pests

Table 18: Commonwealth, State and Territory legislation associated with prevention and management of marine pests

Jurisdiction	Act	Legislative powers	Operational policy
New South Wales	*Fisheries Management Act 1994* (S.182 Declared Disease (includes CCIMPE trigger list of marine pests) & S.209 (noxious fish & marine vegetation).	Can order a quarantine area on the suspicion or presence of a marine pest of concern (CCIMPE listed fish, mollusc or crustacean). Have legislative powers to act on noxious listed species (fish and marine vegetation); can implement fishing closures to minimise translocation from key fishing vectors. Amendments for quarantine provisions for noxious fish are currently underway and are expected to be enacted during 2011.	No biofouling management policy formally communicated
South Australia	*Fisheries Management Act 1997*	Can manage for aquatic exotic organisms (although not defined) and have the authority to stop, assess and instruct vessels that are entering SA waters.	No biofouling management policy formally communicated
Northern Territory	*Northern Territory Fisheries Act 1988* *Northern Territory Fisheries Regulations*	The import or movement of aquatic life (including aquatic pest species) is prohibited without a permit. Whatever action is deemed necessary or desirable to ameliorate the consequences of such an import can be authorised. Control areas may be declared and vessel movements into, within or out of the control area regulated, and the treatment or destruction of aquatic life, water, equipment or other things may be ordered. Schedules of aquatic pests and noxious fish are listed in the Fisheries Regulations..	Vessel inspection protocol applies to vessels entering marinas. Operational policies for the inspection of other vessel types have not been developed.
Queensland	*Fisheries Act 1994*	Can declare quarantine areas to limit the spread of declared or listed noxious marine species.	No biofouling management policy formally communicated
Tasmania	*Living Marine Resources Management Act 1995*	Legislation provides for issuing biosecurity orders with directive powers to control or prevent the introduction or spread of harmful marine pests.	No biofouling management policy formally communicated

Jurisdiction	Act	Legislative powers	Operational policy
Victoria	*Fisheries Act 1995*	Can stop, assess and instruct vessels that are entering Victorian waters. Can act on noxious aquatic species listed under legislation.	No biofouling management policy formally communicated
Western Australia	*Fisheries Resources Management Act 1994* *Offshore Petroleum and Greenhouse Gas Storage Act 2006.* *Environment Protection Act 1986* *Biosecurity and Agriculture Management Act 2007*	Can manage for non-endemic species and can require proponents to implement NIMS management plans using Ministerial Conditions that can be applied to vessels servicing particular projects. Once the BAM regulations are finalised the Act will provide powers to assess, intervene and implement incursion responses.	Currently developing a risk-based approach, and protocol, for assessing vessels entering into and moving around WA waters.
All states and Territories	*Commonwealth Offshore Petroleum and Greenhouse Gas Storage Act 2006 (Administered by the Department of Resources, Energy and Tourism)* *The Quarantine Act 1908*	Requires the development of project-specific, environment plans that specify agreed environmental performance objectives, standards and mitigation strategies that address the management of environmental risk, including risk posed by the introduction of NIMS.	Under current arrangements administration of the environment plans is undertaken by the respective state and territory jurisdictions.

Appendix D Cost benefit assumptions

This appendix outlines the assumptions used in the assessment of the costs and benefits of Option 1 and Option 2 presented in this RIS. Where assumptions refer to a particular section or sections, the section reference is provided.

Assumptions – Option 1

Vessels entering Australia

1. Number of vessel entries into Australia

On average, there are 12,520 vessel entries into Australian waters each year (VMS dataset 2002–2009). The number of international vessels entries per vessel category is provided in the table below. For simplicity of calculation, it is assumed that these numbers will not change over time.

Vessel category	Number of vessel entries per year
Petroleum	
Mobile offshore drilling unit	6
Tug/offshore supply/misc	108
Non-trading vessels	
Barge	13
Dredge	4
Misc	122
Super yacht	23
Yachts	742
Commercial fishing vessels	69
Commercial vessels	
Bulk carrier	7,006
Container vessels	1,709
Cruise vessel	124
General cargo	522
Livestock carrier	340
Ro-ro cargo	386
Tanker	1,347
Total	**12,520**

Note: This excludes the 149 entries per year associated with Illegal Fishing vessels.
Source: DAFF Biosecurity (formerly AQIS) VMS dataset 2002-2009 vessel entries.

Section ref: Various Sections

Identification of risk

2. Initial risk profile of vessels

Based on the results of the MGRA pilot and subsequent adjustments for normalisation, it is assumed that in year 0 of the appraisal the following risk profile for vessels and yachts entering Australia exists:

Risk Level	Vessels	Yachts
Moderate	69%	28%
High	20%	48%
Extreme	11%	24%

Source: DAFF, 2010.

Section ref: 5.2

The raw MGRA results for vessels were adjusted to arrive at the final figure in the table above. Adjustment was made by the Department on the basis that the 2010 MGRA trial overestimated the percentage of vessels in the extreme category. This is due to the fact that a significant proportion of vessels enter Australia more than 4 times a year (This proportion was equal to 15% in 2008-09 based on VMS data, calculation provided by the Department). Under the proposed regulations it is unlikely for a vessel to enter in the extreme category more than 4 times a year as an inspection would have the effect of lowering its risk category for a period of three months and it would be unable to enter if it had not had an inspection since the last entry. Initial rates of high moderate and extreme have therefore been modified to account for this.

It is important to note that mobile offshore drilling units and other vessels associated with the petroleum have been assumed to have the same risk profile as general vessels. This information is currently being verified.

3. '4th consecutive high risk entry' vessel proportion

The proportion of high risk vessel entries that are classified as '4th consecutive high risk entry into Australian waters' (Figure 1) is assumed to remain constant over time. It is assumed that only vessel entries that are not affected by the operating time restrictions will ever fall into this category, as those that are affected must undertake a hull inspection in Australian waters during their first, second, and third consecutive high risk entry. Every time a vessel undertakes an inspection it reduces its biofouling risk and is therefore unlikely to remain in the high risk category for 4 consecutive high risk entries into Australia if an inspection is undertaken every time. The proportion of high risk vessel entries that are classified as 4th consecutive high risk entry is calculated by multiplying the proportion of vessel entries that enter Australia 4 or more times a year (15% – *calculation provided by the Department and based on VMS data for 2008-09)* by the proportion of vessels not affected by the operating time restrictions (56% – refer to assumption 5).

Section ref: 5.2

4. '(1+nth) consecutive extreme entry' category proportion

The proportion of vessels within the '(1 + nth) consecutive extreme entry' category is assumed to be very small, as the penalty of refused entry into Australia is expected to cause the vessel a significant opportunity cost of time wasted travelling to Australian waters. As there is no reliable data available to estimate this figure, a proportion of 1 per cent of all extreme risk entries has been assumed. It is possible for this assumption to be sensitivity tested.

Section ref: 5.2

Implications of risk profile

5. Proportion of vessels subject to OTR

The proportion of vessels subject to operating time restrictions was estimated using the Lloyds Shipping dataset 2002-2007. This dataset provides entry data for vessel entries into Australian waters including the date and port of arrival, the date of sailing from that port, and dates of arrival and sailing for the next ten ports entered. The dataset was used to estimate the proportion of vessels entering Australia from 2002 to 2007 that did not conduct their business within each of the operating time restrictions. It was estimated that:

56% of vessels did not stay longer than 48 hours in any one Australian port.

77% of vessels did not spend more than 8 days in Australian ports all together.

80% of vessels did not spend more than 14 days cumulatively in Australian waters.

This led to the assumption that 44% of vessels required greater than 48 hours in any one Australian port to conduct their business and therefore 44% of vessels would be affected by the OTR of the proposed option.

It is noted that the Lloyds dataset contained some data of an incomplete and inaccurate nature. While effort was made to remove these entries, the data was not cleaned thoroughly before calculations were made.

It is also noted that the Lloyds data set did not provide times but only dates for arrival into and sailing from port. Vessels were assumed to spend 48 hours or less in a port in the case that their arrival and their sailing dates from that port were not more than two days apart. It is possible that this has caused some inaccuracy in estimation. It is reasonable to assume however, that vessels falling within the 56% figure are equally as likely to be under or over the 48 hour time limit.

Section ref: 5.2

6. Moderate risk vessel behaviour

It is assumed that vessels that are currently classified as moderate risk would not undertake any additional biofouling management activities as a result of the regulations.

Section ref: 5.2

Cost assumptions

7. Vessels refused entry into Australia

It is assumed that all vessels refused entry into Australia incur 28 days opportunity costs to travel overseas, and the cost of inspection undertaken overseas.

Section ref: 5.2

8. Costs not included

The following costs have been assumed to be negligible and have therefore not been included in the cost benefit analysis of the regulations:

The costs of verification and audit of a small number of moderate risk vessels

The costs of issuing warning letters to high risk vessels

Section ref: 5.2

9. Treatment cost assumptions

The following assumptions in regards to treatment were made:

In years 1 to 3, all treatment undertaken within Australia must be OOW. This is due to the fact that the Australia and New Zealand Environment and Conservation Council's (ANZECC) *Code of Practice for*

Antifouling and In-Water Hull Cleaning and Maintenance (1997) does not currently allow for in-water cleaning in Australian waters

The ANZECC code is currently under review. Depending on the outcome of the review and on suitable in-water treatment technologies becoming available, controlled in-water cleaning activities may be permitted within Australian waters in the future. From year 4 on, it is assumed that in-water cleaning is permissible in Australian waters and that all DAFF Biosecurity Officer-directed t treatment undertaken within Australia will be in water, except for yachts which will all be treated OOW. This is due to the fact that in water cleaning is cheaper than OOW cleaning as the vessel does not need to be lifted out of the water. Yachts however are smaller and less complex, and based on advice from the Department it is relatively easier for them to be cleaned OOW. Therefore OOW cleaning is assumed for yachts

Some vessels, due to their size, weight and the availability of haul out facilities are not eligible for treatment in Australia in years 1 to 3. The percentage of each vessel type eligible for treatment in Australia in year 1 to 3 was therefore estimated based on discussions with operators of haul-out facilities and available data. The following assumptions were made as a result:

Vessel type	Proportion of vessels that are eligible for OOW treatment in Australia
Petroleum	
Mobile offshore drilling unit	0%
Tug/offshore supply/misc	96%
Non-trading vessels	
Barge	91%
Dredge	75%
Misc	74%
Super yacht	99%
Yachts	100%
Commercial fishing vessels	98%
Commercial vessels	
Bulk carrier	41%
Container vessels	48%
Cruise vessel	52%
General cargo	71%
Livestock carrier	68%
Ro-ro cargo	52%
Tanker	44%

If a vessel is required to undertake treatment in Australia, it is assumed on average to incur 4 days opportunity cost of travelling to a treatment facility.

If a vessel is inspected and must undertake treatment in Australia and is not eligible for treatment in Australia (only applicable in year 1 to 3), then it must leave Australia and travel overseas for treatment. In this instance 28 days opportunity cost of travelling to a treatment facility is assumed.

Estimates of OOW and in water treatment costs, and the average number of days required for treatment were made for each vessel type. Cost estimates were based on a standard commercial team including a qualified marine pest inspector, divers, surface support staff and equipment hire. The following data was used to determine average treatment costs and days required for treatment for vessels in each vessel category:

Results from the general vessel MGRA pilot. These were used to estimate the proportion of vessels that would require a complete clean of the hull and niche areas relative to the proportion that would require a niche area clean only.

In water cleaning cost estimates from Floerl *et al*., (2010).

Vessel size information from the Lloyds MIU dataset.

The table below presents the resulting assumptions for number of days required, in water and OOW treatment costs by vessel type:

Vessel type	Average # of days required for in water treatment	Average treatment cost of in water treatment	Average # of days required for OOW treatment	Average treatment cost of OOW treatment
Petroleum				
Mobile offshore drilling unit	3	$77,550	4.5	$195,000
Tug/offshore supply/misc	0.96	$12,342	1.47	$37,157
Non-trading vessels				
Barge	1.3	$14,119	1.85	$61,000
Dredge	1.51	$22,734	2.12	$96,275
Misc	1.31	$20,441	1.84	$73,888
Super yacht	0.86	$11,033	1.66	$20,605
Yachts	0	$240	0	$575
Commercial fishing vessels	0.89	$11,266	1.48	$25,710
Commercial vessels				
Bulk carrier	2.14	$47,904	2.98	$192,941
Container vessels	2.12	$46,741	2.93	$188,540
Cruise vessel	1.94	$40,082	2.68	$162,394
General cargo	1.69	$25,902	2.26	$116,343
Livestock carrier	1.68	$26,057	2.23	$115,595
Ro-ro cargo	2.1	$45,621	2.9	$185,238
Tanker	2.02	$41,832	2.78	$172,073

Vessels treated overseas (in all years) are assumed to undertake 25% of treatments OOW and 75% of treatments in water. OOW treatments generally incur higher costs and require more time to complete that in water treatments. The extent to which vessels will choose between these two options will depend on a range of factors such as the relative cost differential between the options and the extent to which in water cleaning is allowed in the jurisdiction as well as whether the vessel is being treated OOW for other purposes.

Vessels inspected overseas are treated overseas, and are assumed to incur no opportunity costs of travelling to a treatment facility.

Opportunity costs in dollars were estimated by applying a profit margin of 20 per cent to the estimated daily charter rates for each vessel category and multiplying this by the number of days foregone in treatment or travelling. Refer to assumptions 10 and 11 below in regards to charter rates and profit margins.

Section ref: 6.3

10. Charter rates

Daily vessel charter rates can be extremely variable over time due to fluctuating supply and demand. They also vary significantly due to other factors such as the cargo carried, the region and length of the voyage, labour demand, prices for bunkering, capital depreciation, the ship size, the age, time required for lay-up periods, and the type of contractual agreement in place. Additionally, data on prices is often commercially sensitive and not transparently available.

According to the Milestone Report 3.2.4 Merchant Vessels for vessels entering New Zealand, for example time charter rates for container vessels could range from around US$4,000 per day for a 1200 TEU vessel to US$70,000 per day for an 8,500 TEU Vessel.

Data on daily charter rates was obtained from a range of industry websites, and the NZ Milestone Report 3.2.4 Merchant Vessels. There was little data available on rates over the long term. Data from the Hamburg Index over a period of 5 years (2005 to 2010) was used to compare against the charter rates estimated for containerships, and was found to be relatively consistent.

Where quotes were provided in US dollars, rates were converted to Australian dollars using the 5 year average exchange rate.

As a result, the following charter rates were applied:

Vessel type	Charter rates ($US)
Petroleum	
Mobile offshore drilling unit	$188,681
Tug/offshore supply/misc	$25,081
Non-trading vessels	
Barge	$7,496
Dredge	$29,902
Misc	$29,902
Super yacht	$16,482
Yachts	-
Commercial fishing vessels	$11,628
Commercial vessels	
Bulk carrier	$12,550
Container vessels	$19,074
Cruise vessel	$40,000
General cargo	$15,786
Livestock carrier	$15,786
Ro-ro cargo	$16,000
Tanker	$15,687

Due to the variable nature of these rates, they have been included in the sensitivity testing of costs.

11. Profit margins

Accurate data regarding the profit margins for commercial and other vessels was not readily available for use. Due to the fluctuating nature of vessel profit margins it was difficult to obtain a reliable estimate. 20% was assumed based on the opinion of a consultant with experience of the industry.

Section ref: 6.3

Infection and establishment rates

12. Infection rates

The likelihood of vessels in each risk category to be carrying a SOC (20% extreme, 5% high and 0.1% moderate) have been estimated by the Department based on recent inspections undertaken of vessels arriving in Australia, acknowledging that due to sample size the sampling method may result in over or under estimation. These proportions are able to be sensitivity tested.

Section ref: various

13. Arrival of SOC is Australia

For simplicity it is assumed that all SOC have an equal probability of arriving in Australian waters.

Section ref: various

14. Impact of Establishment

For simplicity it is assumed that all SOC have an equal impact, that impact begins immediately upon establishment and that the rate of impact is constant over time.

Benefit assumptions

15. Reduction of vessels with SOC arriving in Australia

The final number of vessels entering Australia harbouring a SOC each year after implementation of the regulations is calculated by subtracting the number of vessels caught harbouring a SOC (as a result of the additional inspections undertaken due to the regulations) from the total number of vessels entering with a SOC in the absence of additional inspection requirements.

Section ref: 6.3

16. Effectiveness of inspection

The number of SOC likely to be captured through inspection in each risk category is assumed to be the number of vessels in that risk category multiplied by the percentage inspected, multiplied by the likelihood of the vessel to be harbouring a SOC (according to its risk category). This assumes that inspections are 100% effective in that if a vessel harbouring a SOC is inspected, the SOC will be found in 100% of cases.

Section ref: 6.3

17. Calculation of benefits

The difference between the number of SOC to establish under the base case and under the new regulations was calculated on an annual basis for the next 30 years. In order to determine the annual value of the benefits provided by this option, these figures were then multiplied by the economic value at risk per annum from a SOC establishing in Australia.

Section ref: 6.3

18. Economic value at risk of commercial fisheries

The most recent data from ABARE (2011) indicates that the gross value of fisheries production (including aquaculture) in real terms was $2.18 billion in 2009–10. This equates to $2.26 billion in June 2011 dollars. In estimating the economic value at risk of commercial fishing, a more appropriate measure of an industry‘s importance is gross value-added.[8] The value-added component is likely to vary substantially between fisheries reflecting the different levels of profitability of each fishery. It is estimated that approximately 30 per cent of the gross value of production is the value added component of the commercial fishing industry (Econsearch 2007). This is equivalent to $678 million in June 2011 prices.

It is not likely that the introduction of 56 SOC will wipe out the entire Australian fishing industry. Under a worst case scenario, only some proportion of the industry is likely to be impacted. Deep sea fisheries are likely to experience the least direct impact as a result of marine pests. The value of ‘wild caught' seafood makes up approximately 63 per cent of the value of Australian fisheries production (ABARE-BRS, 2010). Using this as a proxy to represent deep sea fish, it is assumed that around 40 per cent of the entire Australian commercial fishing industry is potentially at risk. The economic value at risk from the fishing industry is therefore estimated at $271 million per annum.

This estimate is likely to be an upper bound estimate given that if an establishment occurred it is only likely to impact on some portion of the immediate commercial fishery rather than all locations around Australia.

Section ref: 6.3

19. Economic value at risk of tourism

The direct value of marine tourism and recreational activities in Australia has been estimated as $11.9 billion in June 2011 prices. [9] The Australian Bureau of Statistics estimates the value of output from the total tourism sector for Australia in 2009-10 as $64 billion and the value added component as $31.0 billion or 48% of the total. Applying this proportion to the direct value of marine tourism means the value added component of direct marine tourism can be estimated as $5.7 billion. This means that if an incursion occurred and it impacted on the whole tourism industry, then $5.7 billion of value added might be at risk in any one year.

Only some portion of the $5.7 billion of the value-added associated with the marine tourism sector is likely to be at risk. However, there is limited information available that would assist us to make an assessment of the proportion of marine activities at risk.

The GBR is likely to be the most economically valuable marine environment in Australia at risk from SOC, because the recreation and tourism industry depends heavily on attracting tourists for scuba diving and snorkelling. By comparison, elsewhere in Australia tourism associated with the marine environment is more heavily linked to trips to the beach, surfing, and whale-watching. [10]

Given that the GBR is most likely to be adversely impacted by establishment of a SOC, we have adopted this as the measure of the proportion of marine tourism at risk. The total contribution of the Great Barrier Catchment Area to the Australian economy was estimated to be $5.71 billion in 2005-06 (Access Economics, 2007). Tourism accounted for the largest share of this estimate. The contribution to the total value-added component of tourism of the GBR to the Australian economy was $2.7 billion (June 2010 prices). [11] An additional $114 million per annum in direct value added due to recreational activity is also included, bringing the total impact to $2.8 billion. This is equivalent to $2.9 billion in June 2011 prices.

It is unlikely that all components of the value-added from tourism to the GBR would be at risk of a marine pest. It is more likely that a SOC incursion would diminish the industry, rather than eliminate it. Kragt *et al.*, (2006) found that significant, visible degradation of the GBR potentially caused a maximum 58 per cent decline in reef trips. Applying this factor to the total estimated value-added component of direct tourism of the reef results in a value for the impact on direct tourism of $1.7 billion. This is considered an upper bound estimate. The impacts of the various species would vary and some may have minimal visual impact.

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[8] Value added is the term used to express the difference between the gross value of the fisheries and the costs of materials and labour used in producing them.

[9] AIMS 2010, adjusted to June 2011 prices.

[10] Although there are a considerable number of trips to the beach, therefore, it is possible that in aggregate there is some value at risk related to this activity. However, this would depend on the type of introduced species and how this could impact on these activities.

[11] For the purposes of the analysis in this section we focus on the direct impacts (to avoid a bias given that the indirect impacts on the cost side have not been incorporated).

A SOC incursion on the reef is also unlikely to affect the entire GBR, but it is likely it would be confined to only the local area in which the incursion occurs. In the GBR Catchment there are four statistical divisions (Far North, North, Mackay, and Fitzroy). For the purposes of this analysis it is assumed that if an incursion occurred it would wipe out the value-added of only one statistical division. Assuming that each of the four statistical divisions are equal, then the total value of the tourism/recreation industry at risk per annum is estimated to be $423 million.

Section ref: 6.3

Assumptions – Option 2

Benefits

1. Level of Effectiveness

On the benefits side we have used the same model as the regulatory option, to ensure consistency and allow comparison between the options. We have assumed a level of effectiveness for the use of a voluntary guideline, which is the extent that the information provided, can change behavioural patterns.

As there is no substantive evidence, our main assumption is based on the fact that the voluntary option is likely to be lower than the regulatory option. The voluntary guidelines are not considered to be as compelling for changing behavioural patterns and there is no requirement for the information to be reviewed. Consequently, we have canvassed the voluntary option using an assumption of the relative effectiveness compared with the regulatory option. This allows the option to be considered on the same basis as the regulatory option, and is portrayed as a 'low cost low benefit' approach.

The following sets out how we have applied our assumptions:

Assumptions for Option 1: Regulatory model (from current model)

Vessels:

- High risk vessels – decrease by 10%
- Extreme risk vessels – decrease by 50%

Yachts:

- High risk vessels – decrease by 4%
- Extreme risk vessels – decrease by 15%

Assumptions for Option 2: Voluntary guidelines

Medium Impact: 10% of the current regulatory assumptions (that is, assume that the guideline is 15% as effective of the regulatory model)

Years 1-3

Vessels:

- High risk vessels – decrease by 1%
- Extreme risk vessels – decrease by 5%

Yachts:

- High risk vessels – decrease by 0%
- Extreme risk vessels – decrease by 2%

Year 4

We would assume that the behavioural change in Year 4 is minimal

Sensitivity analysis

To ensure a robust analysis around the voluntary option, we have undertaken a sensitivity analysis around the high and low impacts of the voluntary guidelines. Assumptions for these scenarios have been provided below:

High Impact:20% of the current regulatory assumptions (that is, assume that the guideline is 30% as effective of the regulatory model)

Years 1-3

Vessels:

- High risk vessels – decrease by 2%
- Extreme risk vessels – decrease by 10%

Yachts:

- High risk vessels – decrease by 1%
- Extreme risk vessels – decrease by 3%

Year 4

We would assume that the behavioural change in Year 4 is minimal

Low Impact – 5% of the current regulatory assumptions (that is, assume that the guideline is 5% as effective of the regulatory model)

Years 1-3

Vessels:

- High risk vessels – decrease by 0.5%
- Extreme risk vessels – decrease by 3%

Yachts:

- High risk vessels – decrease by 0%
- Extreme risk vessels – decrease by 1%

Year 4

We would assume that the behavioural change in Year 4 is minimal

Section ref: 6.4

Appendix E Economic studies of non-use values

Economic valuations such as cost-benefit analysis (CBA) do not always provide a complete valuation of environmental resources; instead they only capture the values of market goods that are easily quantifiable. In order to capture the ecological and social costs to environmental quality, non-use values provide techniques for measuring the value of an environmental asset. A non-use value is the economic value arising from a change in environmental quality (or any other situational change) that is not reflected in any observable behaviour.[12]

Existence, option and bequest are the three main types of non-use values which provide further insight into consumer preferences for the environmental resource. These have been outlined below:

Existence Value – Many users hold existence values for environmental resources in that they may not ever make use of the resource but enjoy the satisfaction of simple knowing it exists. The desire to preserve the environmental resource exists regardless of any current or expected future use[13].

Option Value – refers to users who may not intend to use the environmental resource at this point in time, yet wish to have the option of accessing the resource should they wish to change their mind. For example, some users may not wish to visit a national park at the moment but will want to have the option to visit in the future.

Bequest Value – placing value on the fact that future generations will be able to access an environmental resource, in the same state and quality as current generations is known as bequest value.

Some researchers have identified other types of values that can arise within non-use values, such as intrinsic and inherent values. For the purposes of this RIS, the three values outlined above will be used as the basis for assessing non-use values as the additional values often fit within one of the three values. In addition, when applying valuation techniques to measure non-use values, the above values are generally evaluated collectively.

Valuation techniques

There are a number of valuation techniques used to measure the non-use value of an environmental resource, all of which are delivered through survey questionnaire formats. Valuation techniques are generally categorised into two groups, stated preference and revealed approaches. Stated preference approaches use a hypothetical or stimulated environment to reveal non-use values and typically seek to measure a user's reaction to cost increases whereas a revealed approach uses a surrogate environment by asking user's if they are willing to change their behaviour in response to changes in the environment. [14] The types of valuation techniques under these approaches have been discussed below with consideration of advantages and criticisms.

Contingent valuation method (Stated preference approach)

Contingent valuation method (CVM) is a traditional technique for valuing non-use values and has been the subject of continuing criticism and debate. By undertaking a questionnaire survey that stimulates a hypothetical market, a respondent indicates either their willingness to pay (WTP) or willingness to accept (WTA) compensation based on a base case and specific alternative scenario. This creates the potential for results to inform damage assessment (lost passive-use values) where there appear to be no behavioural trials to be followed.[15] Major criticisms of the CVM approach relate to the underlying method surrounding the potential for

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[12] Adamowicz, W., Boxall, P., Williams, M. & Louviere, J.(1998) Stated Preference Approaches for Measuring Passive Use Values: Choice Experiments and Contingent Valuation.

[13] Crowards, T (1995) Nonuse Values and Economic Valuation of the Environment: A Review, CSERFE Working Paper GEC 95-26, University of East Anglia and University College London.

[14] Prayaga, P., Rolfe, J. & Stoeckl, N. (2010) The value of recreational fishing in the Great Barrier Reef, Australia: A pooled revealed preference and contingent behaviour model, Marine Policy, vol 34, pp. 244-251.

[15] Arrow, K., Solow, R., Portney, P., Leamer, E., Radner, R. & Schuman, H. (1993) Report of the NOAA Panel on Contingent Valuation, Report to the General Counsel of the US National Oceanic and Atmospheric Administration, Resources for the Future, Washington, D.C.

various biases to influence value estimates. The report on the National Oceanic Atmospheric Administration (NOAA) panel outlined the following key problems arising from CVM studies[16]:

- CVM can produce results that appear to be inconsistent with assumptions of rational choice
- Responses to CVM surveys can be implausibly large in the view of many programs for which individual's might be asked to contribute and the existence of both public and private goods that might be substitutes for the resource(s) in question
- Relatively few previous applications of the CVM method have reminded respondents forcefully of the budget constraints under which all must operate
- It is difficult in CVM surveys to provide adequate information to respondents about the policy or program for which values are being elicited and to be sure they have absorbed and accepted this information as the basis for their responses
- In generating aggregate estimates using the CVM technique, it is sometimes difficult determining the 'extent of the market'
- Respondents in CV surveys may actually be expressing feelings about public spiritedness or the 'warm glow' of giving, rather than actual willingness to pay for the program in question.

Choice modelling (Stated preference approach)

Choice modelling (CM) is a modern technique for measuring non-use values and has become more popular in recent years as it possesses several advantages over CVM. In particular, CM can distinguish between different attributes of the good being valued which correspondingly allows for eliciting values for environmental goods with multiple attributes.[17]

CM presents respondents with several policy alternatives that are portrayed through a number of attributes with each choice set comprising of a number of profiles or options that depict the alternative scenarios.[18] This approach allows greater flexibility in understanding a respondent's preferences over a range of scenarios and can measure the type or amount of other 'goods' that are required for compensation.

As the CM approach has fewer examples of measuring environmental values than CVM, the disadvantages are not as prominent. Issues that have been identified include information provision, survey design and survey administration which is also evident in CVM. In addition, the design process involves considerable effort in developing relevant scenarios with appropriate attributes and the use of statistical models, this could potentially create difficulties in statistical design as attribute effects are limited by the way they can enter the utility function.[19]

Travel cost method (Revealed preference approach)

Travel cost method (TCM) is one of the oldest non-market valuation techniques that is commonly used to measure non-use values. By undertaking a survey questionnaire, this contingent behaviour technique attempts to reveal values from a surrogate market by estimating demand functions from travel costs.[20] The main advantage of this method is the reliance on market data about travel expenditure and the ability to represent consumer choices and preferences accurately. Representation is depicted through a frequency of visit rates (either individual or a population segment) in terms of travel costs incurred, other site relevant characteristics

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[16] Arrow, K., Solow, R., Portney, P., Leamer, E., Radner, R. & Schuman, H. (1993) Report of the NOAA Panel on Contingent Valuation, Report to the General Counsel of the US National Oceanic and Atmospheric Administration, Resources for the Future, Washington, D.C.

[17] Adamowicz, W., Boxall, P., Williams, M. & Louviere, J. (1998) Stated preference approaches for measuring passive use values: Choice Experiments and Contingent Valuation, American Journal of Agricultural Economics, vol. 80(1), pp. 64-75

[18] Windle, J. & Rolfe (2005) Assessing Non-use Values for Environmental Protection of an Estuary in a Great Barrier Reef Catchment, Australasian Journal of Environmental Management, vol. 12, pp.147-155

[19] Adamowicz, W., Boxall, P., Williams, M. & Louviere, J. (1998) Stated preference approaches for measuring passive use values: Choice Experiments and Contingent Valuation, American Journal of Agricultural Economics, vol. 80(1), pp. 64-75

[20] Eberle, W. & Hayden F. (1991) Critique of Contingent Valuation and Travel Cost Methods for Valuing Natural Resources and Ecosystems, Journal of Economic Issues, vol 25(3), pp. 649-683.

and socioeconomic factors. The opportunity costs incurred and visitation rates are then used to determine recreational values.[21]

Empirical studies on the TCM highlight several disadvantages which has limited the success of this approach. Particularly due to problems with model specification and data limitation, this has resulted in biased results, questioning the validity of the method. Eberle and Hayden (1991) outline the following causes as contributing to this failure:[22]

- The additivity of individual demand functions across sites and across activities to arrive at an aggregate value
- Severe data limitations that restrict the specification of the demand functions to keep them consistent with theory

Hedonic pricing method (Revealed preference approach)

Hedonic Pricing Method is another type of revealed preference approach that is used to estimate the value of environmental facilities that affect prices of marketed goods.[23] This method is not commonly used for measuring non-use values of environmental resources as the method places a large emphasis on variations in housing prices.

Recent economic studies

For the purposes of this RIS no original research has been undertaken to measure the non-use values due to limited time constraints. However an extensive analysis of all publically available literature has been reviewed in accordance with the following criteria:

- Academic studies relevant to the marine context
- Recent and up-to-date studies on non-use values
- Focus on Australian studies with one international example.

The value of recreational fishing in the Great Barrier Reef, Australia – Prayaga, P., Rolfe, J. & Stoeckl, N. (2010)

Prayaga *et al* (2010) recently undertook a study to investigate the responsiveness of recreational fishing demand to changes in costs and other factors such as catch rates and environmental conditions. The study comprised of two sections, using a TCM to estimate the value of recreational fishing in the Capricorn coast and a contingent behaviour model to make predictions about the changes in the value of recreational fishing that would occur in different situations.[24]

Results for the TCM indicate that consumer surplus per current trip is $385.34 per group and $166.82 per angler. By incorporating an annual visit rate of 12.98 trips per year, the recreational fishing by the recreational anglers surveyed generates a consumer surplus of approximately $1.55 million annually. This results in the total annual consumer surplus for recreational fishing along the Capricorn coast to be valued at approximately $5.53 million.[25]

Results for measuring the effect of changes in the conditions along the Capricorn coast indicate that all changes measured comprised of less than 10 per cent of total consumer surplus. Decreasing catch rates by 25 per cent results in a decrease of $110,992 whilst an increase by 50 per cent resulted in an increase of $487,417. This

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[21] Prayaga, P., Rolfe, J. & Stoeckl, N. (2010) The value of recreational fishing in the Great Barrier Reef, Australia: A pooled revealed preference and contingent behaviour model, Marine Policy, vol 34, pp. 244-251

[22] Eberle, W. & Hayden F. (1991) Critique of Contingent Valuation and Travel Cost Methods for Valuing Natural Resources and Ecosystems, Journal of Economic Issues, vol 25(3), pp. 649-683

[23] Ecosystem Valuation (2011) Hedonic Pricing Method, retrieved from http://www.ecosystemvaluation.org/hedonic_pricing.htm

[24] Prayaga, P., Rolfe, J. & Stoeckl, N. (2010) The value of recreational fishing in the Great Barrier Reef, Australia: A pooled revealed preference and contingent behaviour model, Marine Policy, vol 34, pp. 244-251.

[25] Prayaga, P., Rolfe, J. & Stoeckl, N. (2010) The value of recreational fishing in the Great Barrier Reef, Australia: A pooled revealed preference and contingent behaviour model, Marine Policy, vol 34, pp. 244-251.

change is consumer surplus demonstrates the relatively insensitive nature of recreational fishing values to a range of variables such as price, income, crowding, algae and minor change in catch rates.[26]

Effects of Great Barrier Reef degradation on recreational reef-trip demand: a contingent behaviour approach – Kragt, M., Roebeling, P. & Ruijs, A. (2009)

Kragt *et al.*, (2009) undertook a contingent behaviour survey following an identified need for further valuation research on coral reefs. Using a negative binomial (NB) model, the study estimated the recreational demand for reef trips following a hypothetical decline in reef quality, through a reduction in fish and coral biodiversity.

The study indicated that the consumer surplus of current reef visitors who pursue diving or snorkelling trips is approximately $185 per trip. Following a hypothetical decrease in coral and fish biodiversity, results indicate that demand could decrease by up to 80 per cent. A decrease of this size is estimated to reduce reef trip expenditure on commercial vessels by up to 200 million per year. Such results are expected to have significant effects on tourism expenditure to the Great Barrier Reef Marine Park and create further implications for the reef tourism industry.

Assessing Non-use values for Environmental Protection of an Estuary in the Great Barrier Reef Catchment – Windle & Rolfe (2005)

Windle & Rolfe (2005) used a choice modelling technique to measure non-use values for protecting the environmental health of the Fitzroy estuary in central Queensland.

Results indicate the value for the health of the Fitzroy estuary averages $3.21 per household for a one per cent improvement in the health of the estuary. Extrapolating this assumption to a State level produces an approximate value of $647,100. At present, the Fitzroy River estuary covers approximately 110,000 hectares with 75 per cent in relatively good condition. However, if current trends continue Windle & Rolfe (2005) estimate that 65 per cent will be in good condition in 20 years time.

The study also reveals two interesting points on consumer preferences. Values associated with declines in environmental losses are significantly higher than values for improvements in environmental gains. In addition, values for increases in environmental protection experience sharp rises up to a level of 70 per cent yet after this point the slope of the curve flattens out. These results indicate that achieving the highest level of protection may not be the socially optimal behaviour.[27]

Economic Valuation of Nature-Based Tourism Object in Rawapening, Indonesia: An Application of Travel Cost and Contingent Valuation Method – Hakim, A., Subanti, S. & Tambunan, M. (2011)

Hakim *et al.*, (2011) undertook a study to estimate the economic value of Rawapening in Indonesia. Rawapening is a major source of ecotourism for Indonesia and possesses similar biodiversity risks to the Australian ecosystem. In estimating the economic value, the study incorporated both TCM and CVM analysis to determine the economic value of Rawapenging.

Variables that influenced TCM results on the number of tourist visits included experience, travel costs, income, age, gender, education and perception. Key variables determining an individual's WTP was based on the nominal amount expressed, respondent's income per month and education level.

Results found the value of consumer surplus in Rawapening was Rp 7,410 billion whilst the overall value of benefits per year amounted to Rp 1,654 billion.

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The Policy Relevance of Choice Modelling: An Application to the Ningaloo and Proposed Capes Marine Parks – McCartney, A. (2009)

The Allen Consulting Group (ACG) referenced McCartney's (2009) research undertaken on the Ningaloo and proposed Capes Marine Parks in their report to the Conservation Council of Western Australia.[28] The study used a choice modelling approach to value the ecological attributes for the Ningaloo Marine Park and the proposed Ngari Capes Marine Park in Western Australia. Both hold substantial ecological value, particularly the Ningaloo Marine Park where the reef comprises over 90 per cent of the marine park, the largest fringing reef in Australia and a proposed world heritage site.[29]

A web based questionnaire was undertaken from 411 respondents which captured the preferences between different packages of ecological improvements within the sanctuaries based on feasible management options. Ecological improvements were presented as being conditional upon an annual fee and respondents were given the choice of selecting packages according to whether they were prepared to pay a specified fee.

Results from the study indicate that on average, willingness to pay for the Ningaloo and Ngari Capes Marine Parks was $51 per year and $46 per year respectively, for a 5 per cent increase in fish populations. ACG (2009) used these results to calculate the indicative value for a package of ecological improvements. For example, a management strategy in Ningaloo that results in a 10 per cent increase in coral, 10 per cent increase in fish, five per cent increase in turtles and two per cent increase in whale sharks provides a willingness to pay value of $139 per year. Furthermore, by assuming the respondent sample is representative of the Western Australian population aged 19 years and over, the aggregated value to the 1.6 million citizens in Western Australia approximates to $222 million per annum.

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Appendix F Establishment rate

Estimate of the likely establishment rate for non-indigenous marine species in Australia

National System for the Prevention and Management of Marine Pest Incursions

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The opinions expressed in this document are not necessarily those of the Central Queensland University.

Introduction

Marine biological invasions of non-indigenous marine species (NIMS) are now recognised as one of the most pervasive threats to environmental, economic, social and cultural benefits derived from our oceans (eg Lubchenco *et al*., 1991; Carlton 1996, 2001). The need for appropriate management of marine invasions has only recently been appreciated by managers and policy makers (Ruiz and Carlton 2003; Hewitt *et al*., 2009a,b) and has largely focussed on transport mechanisms (ie vectors) such as accidental movements via shipping (ballast water and sediments; biofouling), aquaculture, ornamental and live seafood trade, and also via intentional movements.

Developing appropriate biosecurity approaches to minimise the arrival and establishment of new NIMS requires an appropriate estimate of the marginal benefits any intervention measures would have relative to estimated background rates. Determining the rates of arrival has been the primary focus of research, specifically for ballast water and sediments (eg Carlton 1985; Williams *et al*. 1989; Carlton and Geller 1993), but more recently for biofouling of vessels (eg Coutts 1999; Lewis *et al*., 2003, 2004; Coutts and Taylor 2004), recreational vessels (Bax 1999; Floerl *et al*., 2004), replica sailing vessels (Lewis *et al*., 2006a; pers obs), slow moving barges (Lewis *et al*., 2006b; Coutts 2002), dredges (Clapin and Evans 1995) and oil platforms (Carlton 1987; Page *et al*., 2006).

Determining the actual establishment rate of NIMS however, remains an exercise of estimation due to the large number of unknowns. From first principles, establishment is the stage of the invasion process following from arrival including release from the transport vector, survival of the species sufficient to create a self-sufficient population through sexual or asexual reproduction (eg Williamson 1996; Ruiz and Carlton 2003).

Detection of new NIMS rarely coincides with the actual establishment of a species, but entails some lag period during which the species overcomes physical and biological obstacles in the new environment, and attains growth of the population sufficient to be observed. In the absence of significant effort to detect new incursions, these new populations are likely to remain highly localised (rare in space) and unobserved.

Once detected, these new NIMS must be identified and reported in order for their presence to be noted. This process can create additional lags between the establishment and the reporting of detection. As a consequence, determining establishment rates is fraught with unaccounted errors.

Here we attempt to calculate the establishment rate for NIMS to Australia, specifically those associated with biofouling, and to provide a comprehensive suite of underlying assumptions associated with the calculations.

Calculations and assumptions

A simplistic approach to estimate establishment rate of NIMS in Australia would be to take the known number of established NIMS and divide by the amount of time in which the arrival of NIMS could have occurred. Hewitt and Campbell (2010) developed a global database of recognised NIMS based upon published literature including accessible grey literature and websites. The current estimate of established NIMS in Australia is 226 introduced species and 230 cryptogenic species resulting in a total of 458 species in a conservative estimate[30].

The earliest maritime arrivals to Australia are likely to have occurred in pre-history (Campbell and Hewitt 1999). These arrivals would likely have transferred species from the Indonesian archipelago to northern Australia, however transboundary transport between the Indonesian Archipelago and northern Australia through natural processes (eg currents, wind, rafting) is equally likely.

If we assume that the earliest recognisable marine invasion to Australia occurred with the earliest European arrival, then 410 years have passed since the first visit by Janzoon sighted Cape York in 1601 (Crosby 1986; diCastri 1989; Campbell and Hewitt 1999). Therefore, if we assume that the arrival and establishment of NIMS to Australia (based on detections) occurred at a constant rate over the entire history of arrivals, then the establishment rate would be:

456 NIMS/410 years = 1.11 NIMS/year

The frequency and global distribution of trading relationships however, has increased through time (Campbell and Hewitt 1999; Hewitt *et al.*, 2004; Hewitt *et al.*, 2011) resulting in concomitant changes in frequency of arrivals of species as well as in the diversity of arriving species as new bioregions (and therefore flora and fauna) are added to the trading network. A common approach to this problem is to forensically assess the invasion history of a location (or region) by identifying the earliest dates of detection for recognised introduced and cryptogenic species (eg Carlton 1979; Cohen and Carlton 1995, 1998; Ruiz *et al.*, 1997; Coles *et al.*, 1999; Hewitt *et al.*, 1999, 2004).

Analyses of the temporal distribution of detection rates in Port Phillip Bay, Victoria (Thresher *et al.*, 1999; Hewitt *et al.*, 2004) demonstrated that detection rates were not constant through time, but had increased since 1960. This pattern held for all NIMS, but was very pronounced for high profile, readily identifiable macrofauna (ie fish, echinoderms and molluscs) whose search effort could readily be verified in the literature (Figure 1). Following the Thresher *et al.*, (1999) assessment, we have evaluated the currently known suite of NIMS in Australia.

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[30] An additional 6 species that are native to one region of Australia are known to have been introduced to another but are not considered further in this assessment.

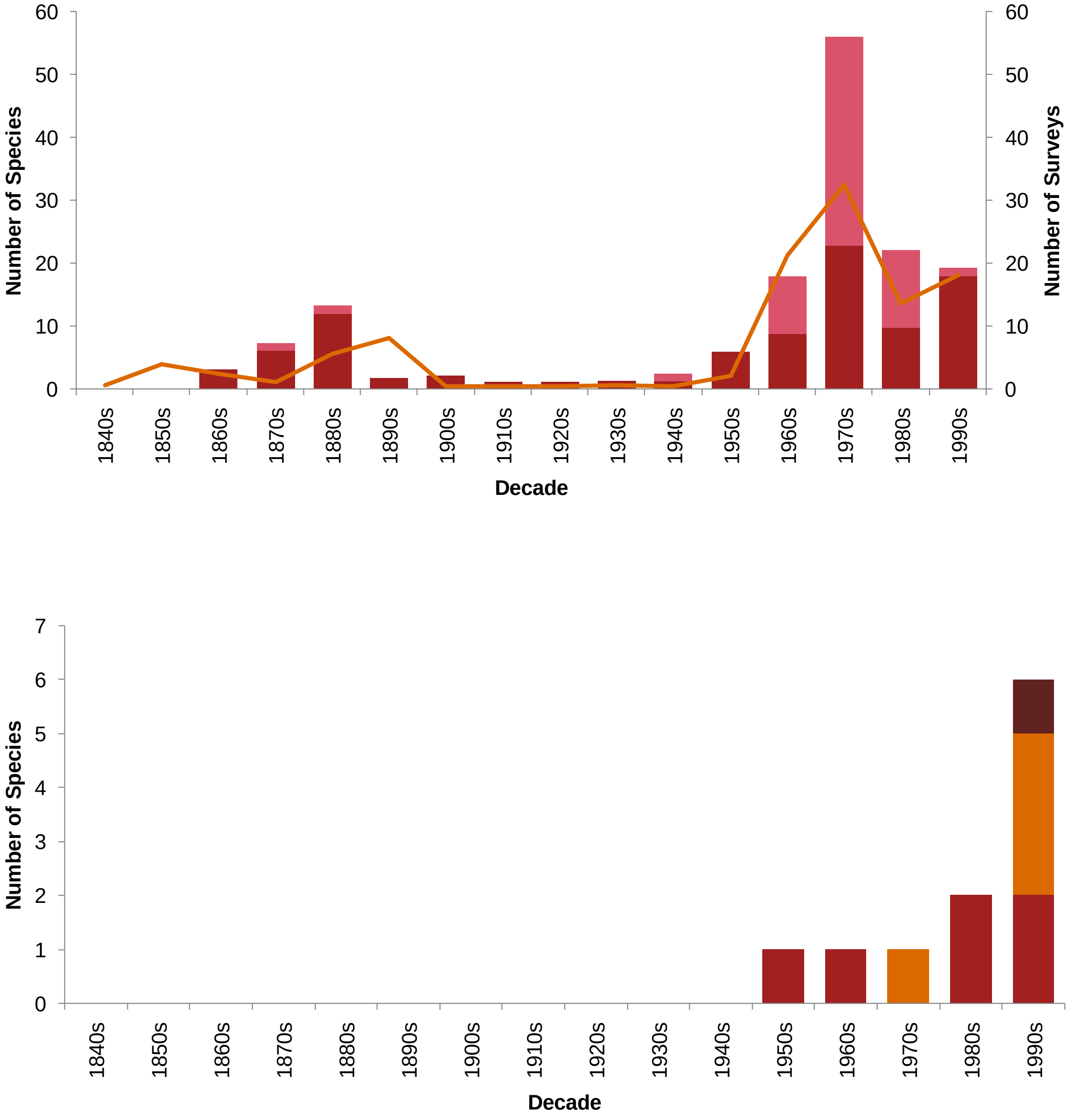


Figure 3: First reports of NIMS by decade in Port Phillip Bay, Victoria (reproduced from Hewitt *et al.*, 2004). a) Numbers of (shaded bars) introduced and (open bars) cryptogenic species identified and the numbers of bay-wide floral and faunal surveys (solid line) per decade in PPB. b) Numbers of introduced species for commonly surveyed groups per decade in PPB; numbers of (solid bars) molluscs, (shaded bars) fish, and (open bars) echinoderms

Of the 458 NIMS recognised in Australia, we have recorded reliable detection dates for 123 NIMS. Plotting the distribution of detections in decadal increments (Figure 4) supports the previous observation for PPB that the rate of detected and established NIMS have significantly increased since 1960. Of the 123 NIMS for which we have reliable detection dates, 64.2% (79) have been detected and recorded during the last 60 years (since 1960).

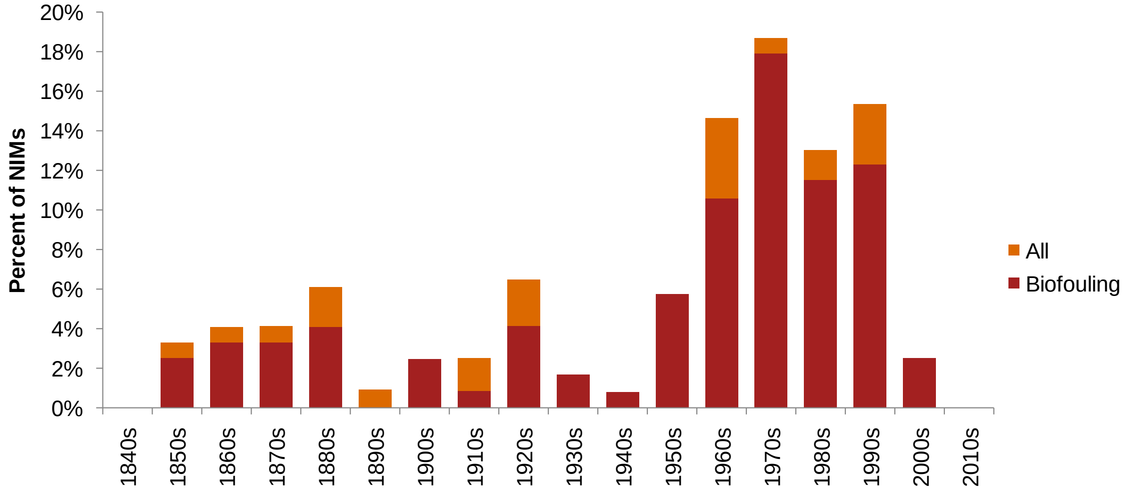


Figure 4: Frequency of detection dates for 123 NIMS to Australia (Hewitt and Campbell unpub data); Dark bars represent species which have life history characteristics likely to be associated with biofouling.

Using this subset of 123 NIMS for which we have reliable detection information as representative, we can estimate the number of NIMS that have arrived since 1960 by

458 NIMS x 64.2% = 294 NIMS having arrived since 1960

Therefore the estimated recent rate of establishment over the last 60 years becomes

294 NIMS/60 years = 4.9 NIMS/year since 1960

Biofouling species rate

The global average percentage of species with biofouling association determined by Hewitt and Campbell (2010) was 55.5%, ie 55.5 percent of the global dataset had life history characteristics that would infer an association with biofouling. An assessment of the Australian dataset however indicates that 69.2% of detected NIMS have an association with biofouling (Hewitt and Campbell 2010). The 123 NIMS for which we have reliable information had a high average of biofouling association (82.9% across all years) and no significant difference in the biofouling association percentage was detected before vs. after 1960 (t.05[14] = 0.48, ns).

Therefore, we estimate that the current establishment rate of 4.9 NIMS/year, between 69.2% and 82.9% will have an association with biofouling. This provides a range of establishment rates between 3.39 and 4.06 NIMS/year that are anticipated to have a biofouling association.

Likelihood of at least one of the biofouling SOC arriving

The likelihood of new species arriving to Australia and subsequently establishing has been evaluated in Hewitt *et al.*, (2011a,b) resulting in the identification of 56 biofouling Species of Concern (SOC).

If we assume that the species arrivals to Australia are of equal likelihood, then the most simplistic assessment would be to ask what is the probability that the 3.39 and 4.06 NIMS arriving year sampled from the global pool of species will include at least one of the biofouling SOC. To undertake this assessment we must ascertain the global pool of species from which a sampling will occur.

The current global assessment of species by Hewitt and Campbell (2010) identified 1781 NIMS with recognised invasion history at some location globally. Of this number, we know that 458 NIMS are recognised from Australia, and an additional 255 species are native to Australia but have been introduced to other locations (including internal to Australia) resulting in

1781 global NIMS – 458 NIMS in Australia – 255 native Australian NIMS = 1068 NIMS not present in Australia

If we assume that this is an accurate representation of the species pool for future invasions, then the 56 biofouling SOC represent 5.42% of the total pool. To determine the likelihood of one of the biofouling SOC arriving and establishing as one of the 3.39 and 4.06 NIMS arriving and establishing per year, we calculate the probability of at least one biofouling SOC as

$$P \text{ at least one SOC} = 1 - \pi(1\text{-proportion of total NIMS pool}) \qquad \text{Eqn 1}$$

Where the proportion of SOC to the total pool is 0.52 and i = the rate of annual arrivals between 3.39 and 4.06 NIMS arriving year. This calculation results in a probability estimate of 0.15 to 0.2 (or 15% to 20%) likelihood that one of the arriving and establishing NIMS will be a biofouling SOC on an annual basis.

Biases

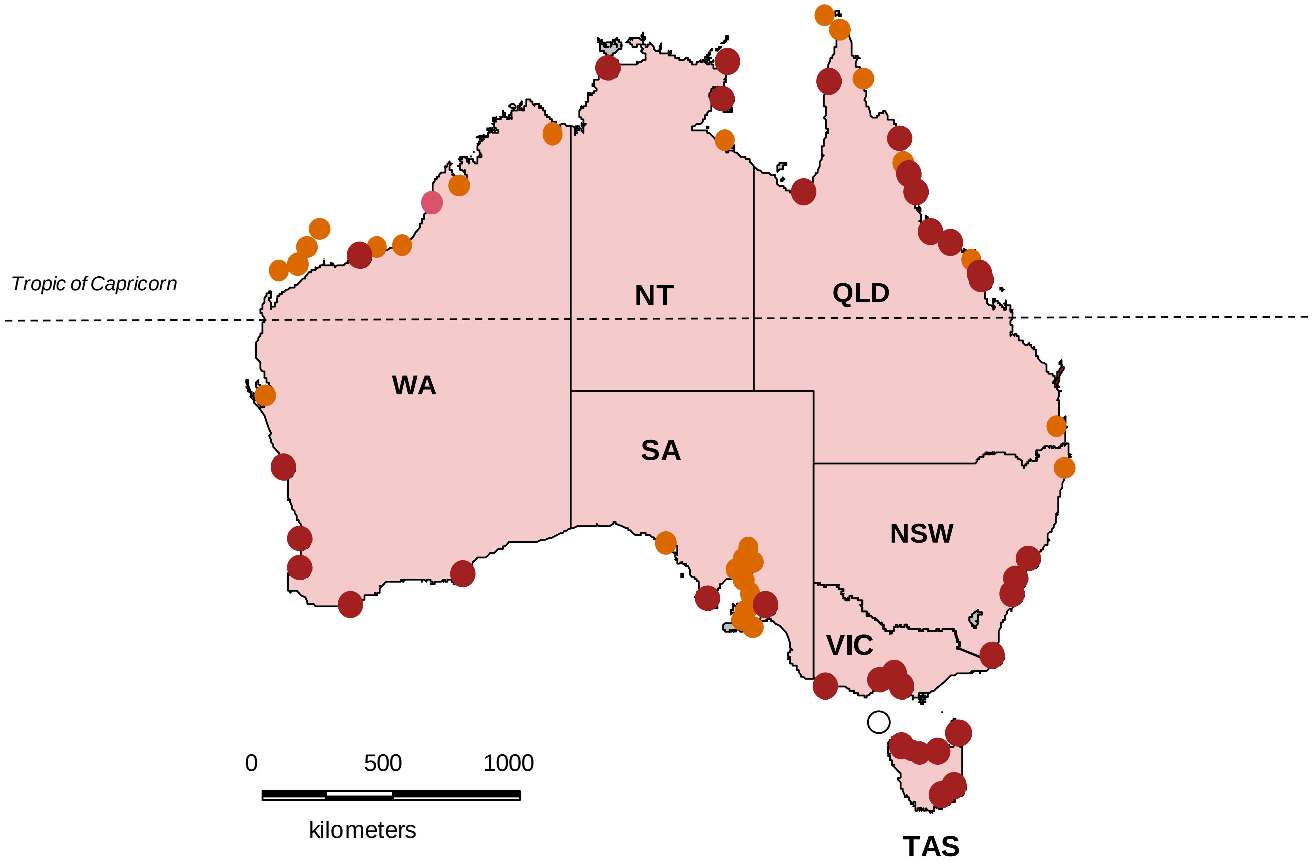
These estimates are based on the assumption that the global species pool and the Australian NIMS are completely known and the detections represent the complete data set. It is considered however that these numbers are likely to be significant underestimates globally (Ruiz *et al.*, 1997, 2000; Hewitt 2003; Ruiz and Carlton 2003).

For example, despite Australia having one of the best understandings of the scale and scope of NIMS through the significant investments that have occurred since the early 1980s (eg Hutchings *et al.*, 1987; Williams *et al.*, 1988; Kerr 1994; AQIS 1995). These investments resulted in a significant increase in the understanding of NIMS presence in Australia. Pollard and Hutchings (1990 a and b) undertook an investigation of recognised NIMS through evaluations of the literature and Australian Museum collections resulting in a recording of 62 species.

The establishment of the Centre for Research on Introduced Marine Pests (CRIMP) in CSIRO had a primary focus on determining the scale and scope of marine invasions in Australia through a focussed assessment of Port Phillip Bay, Victoria (Hewitt *et al.*, 1999, 2004) and the development of the Australian National Port Baseline Surveys programme (Hewitt and Martin 1996, 2001; see also Hewitt 2002; Campbell *et al.*, 2007 and Hewitt and Campbell 2010). The evaluation of Port Phillip Bay (PPB), Victoria, based on surveys and assessments of the literature and museum collections, identified 154 NIMS (93 introduced and 61 cryptogenic species) in PPB alone (Hewitt *et al.*, 2004).

The Australian National Port Baseline Surveys programme sampled 34 Australian ports between 1995 and 2002 (Figure 3) using a consistent suite of standardised methods for design and sampling across a range of habitats (Hewitt and Martin 1996, 2001; see also review by Campbell *et al.*, 2007). These surveys were initially undertaken to provide baseline information (providing spatial invasions data) and subsequently, if funds existed, resurveys using the same methods and sampling intensity would occur (providing both spatial and temporal invasion data). The frequency of resurveys should be dependent on the baseline data and the introduced species detected. In practice, resurveys have occurred infrequently, and where they have occurred, at 6-month intervals (eg Darwin wet and dry season surveys), three year intervals (eg New Zealand port surveys), and five year intervals (eg Bunbury, Western Australia, resurvey). To date, the Hewitt and Martin protocols have been used in more than 73 surveys in 12 countries and represent 66% of the formal evaluations for marine invasions across the globe (Campbell *et al.*, 2007).

Figure 5 Australian ports and facilities with surveyed locations noted in red (from Hewitt and Campbell 2010).



As a direct result of the CRIMP initiatives, including the assessment of PPB, the establishment of the Australian National Port Baseline Survey programme and the development of the National Introduced Marine Pests Information System (Hewitt *et al.* 2002; NIMPIS 2009) and continued efforts of the author, we now understand that the current estimate of established NIMS in Australia is 226 introduced species and 230 cryptogenic species resulting in a total of 456 species as an informed estimate[31].

So we can use the Australian 'discovery' of the scale and scope of NIMS presence as an estimate of the unknown numbers of global NIMS. Assuming the Pollard and Hutchings (1990a,b) estimate of 62 as a baseline prior to significant investment and the current estimate of 458 species as an accurate number, then

458 NIMS/62 NIMS X 100 = 739% increase in NIMS knowledge

These calculations assume that all available NIMS have an equal likelihood of arrival. While disparate global distributions of species and the differential trading activities with various bioregions contradict this assumption, the 56 biofouling SOC presented in the Biofouling Species Risk Assessment (Hewitt *et al* 2011a) were selected as a direct consequence of their increased likelihood of arrival.

Discussion and conclusions

Australia has demonstrated significant commitment to understand the scale and scope of invasions in its near shore marine environments through a variety of intervention measures including establishment of the CSIRO Centre for Research on Introduced Marine Pests (CRIMP), support for the development of the Australian National Port Baseline Survey programme, and the establishment of the National System for the Prevention and Management of Marine Pest Incursions.

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[31] Note however that even this number is assumed to be an under-estimate due to the lack of holo-planktonic species and numerous small groups.

The development of new intervention measures, specifically designed to regulate the vectors likely to transport new NIMS into Australian waters must demonstrate an increased value over the current activities. Here we provide an estimate of NIMS establishment rates with an explicit statement of assumptions and relate these estimates back to the probability that at least one of the biofouling SOC will arrive in any given year.

A number of biases have been identified in various analyses of establishment across the globe (eg Coles *et al.*, 1997; Ruiz *et al.*, 1997, 2000; Hewitt *et al.*, 1999, 2004), including differential collection (search) effort through time; taxonomic biases associated with limited expertise at various periods; and time lags between detection, identification and publication. For example, the majority of algal invasions to Port Phillip Bay, Victoria have been recorded post 1950, largely as a consequence of critical evaluation (Thresher *et al.*, 1999).

Many of these biases can be accounted for with effort, while others cannot. For example, undersampling through time, specifically in the earliest periods of colonisation cannot be rectified. Coles *et al.*, (1997) attempted to normalise the apparent invasion histories according to search effort by comparing NIMS detections with new species discoveries and descriptions (assuming similar time-lags). Similarly, Hewitt *et al.* (1999, 2004) attempted to account for taxonomic biases (and lack of expertise) by restricting the assessment to phyla for which a strong and consistent taxonomic expertise was maintained through time.

The result of this study is that we calculate an establishment rate of between 3.39 and 4.06 novel NIMS arriving per year from the known global pool of NIMS (1068 NIMS). While we anticipate that this global pool may increase with increased knowledge (possibly by as much as 735%) we can estimate the probability of at least one of the 56 biofouling SOC being represented in the known global NIMS pool to range between 0.15 to 0.2 (or 15% to 20%).

Appendix G Glossary of terms

Term	Definition
Antifouling coating	A coating applied to submerged surfaces to prevent or reduce the settlement and growth of biofouling organisms. Antifouling coatings are generally applied as a paint and include biocidal coatings and fouling-release coatings.
Australian waters	Includes State and Territory coastal waters, territorial sea, contiguous zones and Australia's Exclusive Economic Zone which extends to a distance of 200 nautical miles (370 km) from Australia's coastline. This also includes the Joint Petroleum Development Area, an area of the Timor Sea with overlapping territorial claims between Australia and Timor Leste.
Behavioural change	The anticipated amendment of biofouling management practices for vessel husbandry
Ballast water	The water and associated sediments taken on board a vessel to manage the trim and stability during a voyage.
Benthic	Pertaining to the flora and fauna found on (or associated with) the ocean floor.
Biofouling	The undesirable accumulation of marine organisms, such as microorganisms, algae and animals on surfaces and structures submerged or exposed to the marine environment. Biofouling can occur on wharves and jetties, vessel hulls (including rudders, propellers and other hull appendages), internal seawater systems (including sea-chests and pipe work), and equipment such as mooring devices and anchor wells.
Bioregion	A large area of land or water that contains a geographically distinct assemblage of communities that share similar environmental conditions.
Biosecurity	Refers to the management of the risks associated with pests and diseases entering, establishing or spreading that threaten the economy, environment, human health or social values.
Biosecurity risk	The potential harm to the economy, environment, human health and social values posed by pests and disease entering and establishing in Australian waters.
Colonisation	The settlement and successful establishment of larvae or propagules on a submerged substrate.
Commercial vessel	A vessel that carries or exchanges commodities or people. This vessel category includes: asphalt tankers, bulk carriers, bulk carriers with container capacity, bulk cement carriers, bulk ore carriers, bunkering tankers, chemical tankers, combined bulk and oil tankers, combined chemical and oil tankers, combined LNG and LPG gas carriers, combined ore and oil carriers, crude oil tankers, fully cellular containerships, general cargo ships with container capacity, liquid natural gas carriers; liquid petroleum gas carriers, livestock carriers, passenger (cruise) ships, passenger roll-on roll-offs, reefers, roll-on roll-offs, roll-on roll-offs with container capacity, tankers (unspecified); vehicle carriers and wood-chip carriers.
Consequence	The likely impact or magnitude of an event or hazard.

Term	Definition
Cumulative time in Australian ports	The maximum cumulative amount of time that a vessel can spend in Australian ports under Operating Time Restrictions is 8 days (with a maximum of 48 hours in each individual port). Vessels may visit multiple Australian ports provided they do not visit the same port twice, and that the summed total time does not exceed 8 days. After 8 days the vessel will be directed to leave.
Cumulative time in Australian waters	The maximum allowable amount of time that a single vessel can spend in Australian waters under Operating Time Restrictions i 14 days. After 14 days in Australian waters vessels will be required to leave.
Demonstrable impact	An impact that has been scientifically demonstrated through observation and/or empirical evaluation.
Dry and semi-dry ballast	The largely historic (though some vessels still use dry ballast) use of rocks, cobble, sand and other dry substances to help maintain the trim and stability of a vessel. Semi-dry refers to the wet nature of the bilge, providing a humid environment.
Endpoint	An expression of the thing(s) that you are trying to prevent, achieve, protect or manage through risk analysis. Endpoints in a marine biosecurity context are generally either biosecurity based (prevention of entry) or impact based (prevention of impact).
Establishment	The process where a species that is introduced into a new environment survives and develops a self-sustaining population.
Fishing vessels	Legal commercial vessels engaged in capturing wild stocks of living marine resources, such as fishing (general), trawler (all types), whaler, fish carrier and fish factory vessels.
Hazard	A situation that, in a particular circumstance, could lead to harm. The product of the measure of likelihood of these circumstances and the magnitude of the subsequent harm (consequence) is a measure of risk.
Hull	The wetted (submerged) surfaces of a vessel, including its propulsion and steering gear, internal cooling circuits, sea strainers, bow and stern thrusters, transducers, log probes, anchors, anchor chains, anchor lockers and bilge spaces.
Indigenous or Native	Species that are naturally occurring in a region, or having migrated into a region without human intervention.
Infect	The transferral of a species to anew surface or location via a transport vector (vessel), such as the settlement of planktonic larvae onto a vessel hull.
Infection rate	The likelihood of vessels in each risk category to be carrying a species of concern
Inoculate/inoculation	The release of a NIMS into the surrounding environment. This includes the release of offspring, fragments and/or direct transfer of individuals, but does not infer successful establishment.
Introduced/non-indigenous/exotic marine species	Species that have been transported by human activities — intentionally or unintentionally — into a region outside their natural distribution.
Introduction	The human-mediated movement of a species to an area outside its natural range.

Term	Definition
Invasive species	A species that causes, or is likely to cause, damage to the environment, economy (for example, agricultural or aquaculture activities, wild fisheries stocks), social values or human health.
Likelihood	The probability or frequency of an adverse event or hazard occurring.
Marine pest	Any exotic marine species that poses a threat to the marine environment, economy (industry), social values or human health if introduced, established or translocated.
Niche area	An area on a vessel or movable structure that is more susceptible to biofouling accumulation due to different hydrodynamic forces, susceptibility to anti-fouling coating wear or damage, or being inadequately or not covered with anti-fouling coatings. Niche areas include, but are not limited to: waterline, sea chests, bow thrusters, propeller shafts, inlet gratings, jack-up legs, moon pools, bollards, braces and dry-docking support strips.
Non-trading vessel	A category of ship that includes: barges,, cable ships, crane ships, cutter suction dredgers, dredgers, ferries, fire fighting tugs, fire fighting tug supply ships, fishery protection; grab dredgers, hopper barges, hopper dredgers, icebreakers, landing craft, lighthouse/tender; meteorological research; oceanographic research; patrol ships, pollution control vessels, pontoons, pusher tugs, research ships, research/supply ships, salvage tugs, semi-submersible heavy lift vessels, suction dredgers, tank barges, trailing suction hopper dredgers, tugs, tug/supply; yachts >25 m or super-yachts.
Propagules	The offspring of aquatic invertebrates (larvae) and algae and/or individuals.
Recipient port	The port to which species are transported to from other ports or regions.
Recreational vessel	A non-commercial vessel whose primary use is for recreation, intended to be operated by, and carry at least one person within the confines of a hull. Windsurfers, surfboards, rafts and tubes are not considered recreational vessels. Recreational vessels are restricted to vessels <25 m and recreational vessels >25 m reported as 'Non-trading vessels' due to capture under different regulatory controls in Australia.
Risk	The product of likelihood (frequency) and magnitude (consequence) of an event or hazard. And in layman's terms this means…
Risk assessment	The method of determining the likelihood (frequency) and consequences (magnitude) of events (risks). In a marine biosecurity context, risk assessment consists of five steps: identifying endpoints, identifying hazards, determining likelihood, determining consequences and calculating risk.
Sea-chests	Sea-chests are recesses built into a vessel's hull below the waterline that house the seawater intake pipes used for ballast uptake, engine cooling, fire fighting and other onboard functions.
Settlement	The process of planktonic larvae transferring from the water column to the benthic substrate, usually associated with metamorphosis to adult morphology. Settlement does not always lead to recruitment.
Spread	The movement and establishment of a species, either by natural or human-mediated means, into new locations.
Time in Australian waters	See Cumulative time in Australian waters
Time in Australian port	See Cumulative time in Australian ports
Time-in-port	The maximum allowable time

Term	Definition
Translocation	The movement of an organism from one place to another.
Transport pressure	The number of vessels that arrive from a particular bioregion multiplied by a port duration weighting. This number was then summed within each of the 18 bioregions. For each species the weighted number of vessels arriving from all bioregions where the species was present was summed providing a cumulative number of vessel opportunities for that species to be transported into Australia. This value was then divided by the unweighted number of vessels entering Australia to provide the percentage of total opportunities for entry.
Vector	The physical means which facilitates the translocation of organisms or their propagules from one place to another. In a marine biosecurity context this includes ships' ballast water, ships' hulls, the movements of commercial oysters and live seafood.
Vessel	Any craft that operates in a marine environment, be it to transport people or commodities, to carry out maintenance or to provide a platform for other activities. Vessels include: ships, barges, mobile drilling units, work boats, and submersibles..

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