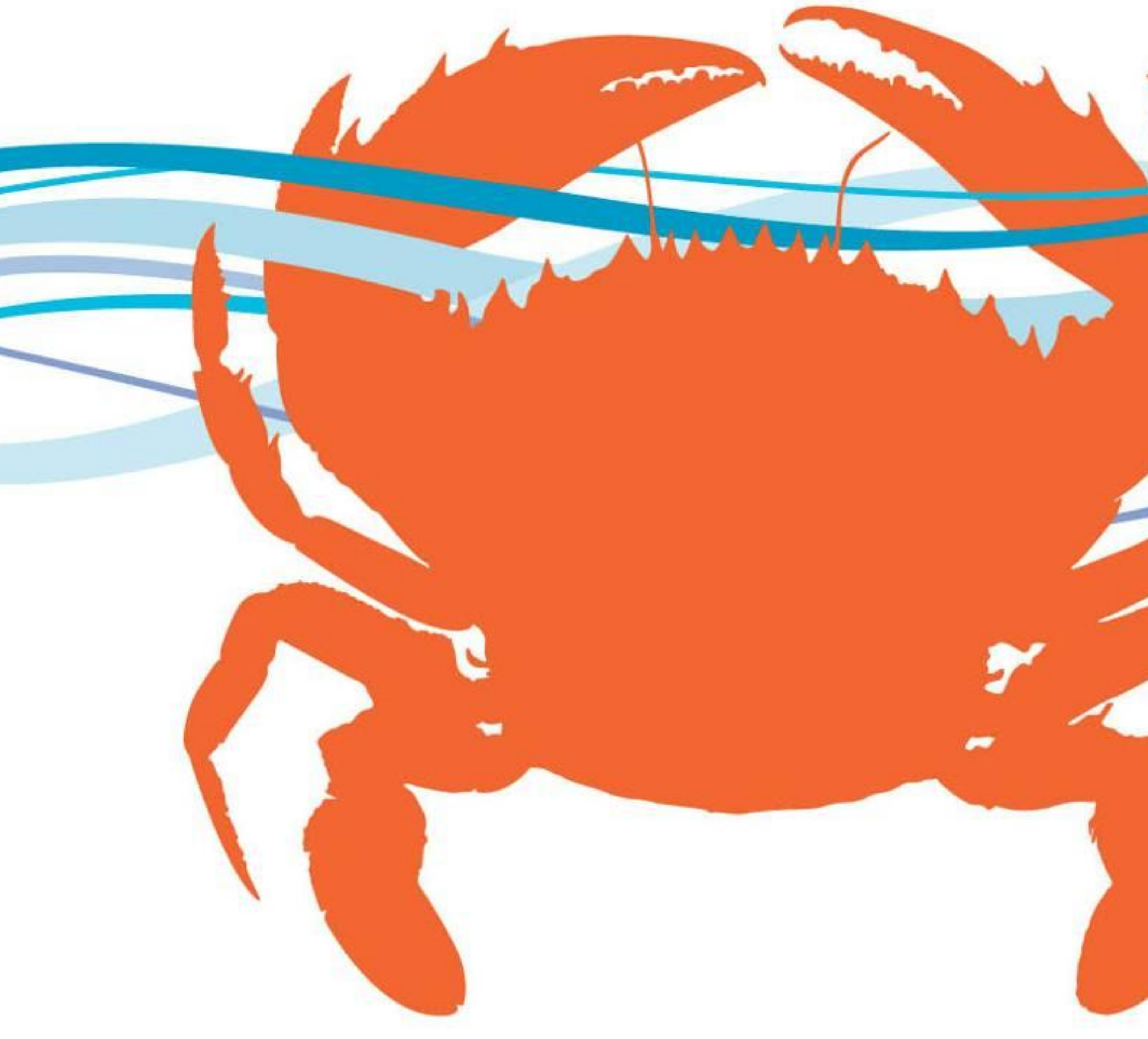
THE NATIONAL SYSTEM FOR THE PREVENTION AND MANAGEMENT OF MARINE PEST INCURSIONS

An Australian Government Initiative

SPECIES BIOFOULING RISK ASSESSMENT



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February 2011

ISBN: 978-1-921575-18-1 high res for print

978-1-921575-19-8 low res for web pdf

SPECIES BIOFOULING RISK ASSESSMENT

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Summary

Marine biological invasions have increased throughout the world's oceans to the extent that no region is considered 'pristine'. At least 1781 species have been identified as introduced in marine or estuarine systems somewhere in the world. Many of these species have been introduced to several regions, inferring an ease of transport by human-mediated mechanisms. A substantial number of these species have either demonstrable or inferred impacts.

Marine species have been transported around the world in many ways, both intentionally and accidentally. Concern has typically focused on vessel traffic, specifically the transport of species in ballast water, which is used for trim and stability of commercial vessels. This led to the development of the International Maritime Organization's International convention for the control and management of ship's ballast water and sediments that was adopted in 2004.

More recently, attention has shifted to species that attach to the external surfaces of vessels, including commercial, fishing, and non-trading vessels such as barges, dredges, tugs and recreational yachts. Such species are collectively known as biofouling.

Science-based risk assessment is a key element of Australia's biosecurity system and underpins the nation's biosecurity policies. However, there are currently no Australian regulatory measures for preventing the introduction of invasive marine species through biofouling.

The objective of this project was to conduct a risk assessment to identify and assess the biosecurity risk to Australia associated with the entry, establishment and spread of marine pest species as biofouling. This risk assessment is therefore intended to inform Australian Government policy development for continued management of marine pest risks as biofouling.

The risk assessment followed a five-step process:

- identifying endpoints
- identifying hazards
- determining consequences
- determining likelihood
- calculating risk.

Risk was evaluated across three identified endpoints: inoculation, establishment and spread. International voyages to Australia were assessed for the risk they pose in relation to inoculation and establishment. Likelihood of domestic spread was assessed through analysis of domestic movement of international shipping, other domestic vessel movements/traffic and through natural means.

Key hazards for Australia were deemed to be those species with a recognised invasion history, but not currently known to be present in Australian waters. More than 1781 species that have been identified as being introduced to some region of the world were evaluated for their association with biofouling and transport pressure. Species association with biofouling was assessed on the basis of life history characteristics. Transport pressure was calculated as a function of the intersection between a species' global distribution and the opportunities for transport calculated as a combination of the number of vessels arriving in Australia from regions where a species is present.

The consequence (or impact) was assessed for each species on four core values of environment, economic, social/cultural and human health, based on information derived from the literature. The vast majority of species had neither demonstrable nor inferred impacts stated in the published literature, significantly decreasing the ability to assess risk. For those species with available information about their consequence, risk was calculated as the product of likelihood and consequence. The result of this analysis was a restricted suite of 56 species that have a high probability of arrival into Australian waters and the potential to cause moderate to extreme impacts across one or more of the four core values if successfully introduced.

1.0 Introduction

1.1 Background

The expansion of species ranges in geological and ecological time is a result of both natural and human-mediated processes, collectively referred to as biological invasions (Carlton 2001). Natural processes, typically referred to as range expansions, occur over long timeframes and generally result from the breakdown of biogeographic barriers between adjoining biogeographic provinces. In contrast, human-mediated movements of species, known specifically as biological introductions, occur in ecological timeframes of weeks to years and transcend the geographies of natural species' range expansions. The human-mediated movements of non-indigenous marine species have occurred intentionally and accidentally for thousands of years (diCastri 1989). Intentional movements of species have occurred for both agricultural and cultural reasons (Elton 1958; Crosby 1986; Diamond 1998). Intentional and accidental movements have increased through time, largely tracking European expansion (Crosby 1986; diCastri 1989) and resulting in significant alterations to modern ecosystems (e.g. Vitousek et al. 1996).

The early recognition of human-mediated transport by Ostenfeld (1908) and Elton (1958), allowed for development of an understanding of patterns and process in recent decades (e.g. Carlton 1985, 1996, 2001; Williams et al. 1988; Ruiz et al. 2000; Hewitt 2002; Castilla et al. 2005; Minchin 2006).

Marine species can be transported via a variety of mechanisms including:

- boring into wooden-hulled vessels (e.g. Turner 1966; Carlton & Hodder 1995)
- biofouling of organisms on vessel hulls and in niche areas including sea-chests and internal pipe work (e.g. Ribera & Boudouresque 1995; James & Hayden 2000; Gollasch 2002; Coutts et al. 2003; Fofonoff et al. 2003; Coutts & Taylor 2004; Coutts & Dodgshun 2007; Davidson et al. 2009)
- the historic use of dry and semi-dry ballast (e.g. Ruiz et al. 2000; Carlton 2001)
- ballast water transport of planktonic and pelagic organisms, including species fragments (e.g. Ostenfeld 1908; Carlton 1985; Carlton & Geller 1993; Fofonoff et al. 2003)
- intentional transfers of aquaculture organisms, specifically oysters (e.g. Elton 1958; Carlton 1989; Cook et al. 2008)
- unintentional movement of associated organisms including pathogens, parasites, epifaunal and infaunal organisms (e.g. Elton 1958; Carlton 1989, 1996; Hewitt et al. 2006, 2007, 2009c; Cook et al. 2008)
- deliberate transfers of aquaculture food products such as live, fresh or frozen materials (e.g. Hewitt et al. 2006; Cook et al. 2008)
- biofouling of aquaculture gear (e.g. Hewitt et al. 2006; Cook et al. 2008)
- transfer of live, fresh, frozen and dried food products and live aquarium products (e.g. Weigle et al. 2005)
- use of biological material for packing (e.g. Ribera Siguan 2002, 2003; Miller et al. 2004)
- transport of species for scientific research (e.g. Carlton 2001).

In many cases, these transport mechanisms, often referred to as vectors in marine biosecurity, have facilitated the translocation of multiple species and often entire assemblages of tens to hundreds of species between disparate bioregions. They frequently continued over long periods, inoculating receiving environments with propagules or new individuals over multiple generations (e.g. Carlton & Geller 1993; Ruiz et al. 2000; Hewitt et al. 2004).

While it is difficult to establish a firm link between an already established non-indigenous marine species and the vector by which it arrived in the new location, attempts have been made to do so. Inferences, based on reasoned argument, have largely been based on life history modes, timing of invasions, and association between location of incursion and vectors. Table 1 presents results of several studies from around the globe that have estimated the proportion of non-indigenous marine species that may have been translocated as biofouling.

Hewitt et al. (1999, 2004) conducted an evaluation of introduced species to Port Phillip Bay in Victoria (Australia) and identified the most probable vector(s) of transport for individual species based on the biology of each species' life history phase (e.g. planktonic larvae for ballast water, attached benthic phase for vessel biofouling) and the timing of invasions (e.g. before or after the advent of ballast water use). In that study, the assignment of species to vectors was not exclusive and where life history or evidence indicated, species were assigned to multiple vectors. Any vector by which a life history phase could be transported (see expert chapters in Hewitt et al. 1999) and was operating at the time of first collection, was given equal weighting. The generated summary was based on a percentage of all species components contributing to each vector.

Hewitt and Campbell (2010)[1] provided an assessment of the current state of knowledge of marine and estuarine invasions on a global scale, using techniques similar to the evaluation of Port Phillip Bay described above. The 2008 study of available literature found 1781 species worldwide had been introduced into bioregions outside their native range. Species associated with biofouling of commercial merchant and fishing vessels, and aquaculture biofouling represented 55.5% (±9.4% SD) of the total species. It is these 1781 species that form the basis of this risk assessment.

Table 1: Results of global studies investigating the percentage of non-indigenous marine species that can be 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 and Carlton 2002
North Sea	>50%	Gollasch 2002
North America (USA)	70%	Fofonoff et al. 2003
Port Phillip Bay, Australia	78%	Hewitt et al. 1999, 2004
Australia (national port surveys)	59%–69%	Hewitt and Campbell 2010
Japan	42%	Otani 2006
Global (algae)	70%	Hewitt et al. 2007
Global (all taxa)	55%	Hewitt and Campbell 2010

[1] This publication may be referenced elsewhere in this document as Hewitt and Campbell (2008).

1.2 Assessment rationale

Recent agreement on international and national management approaches to issues associated with ballast water vectors, and increased concern over biofouling species, has led to development of this project to assess marine pest biofouling risks into Australian waters[2].

Global marine biosecurity efforts for the past several decades have focused on ballast water- (and sediment) mediated species transfers, with several nations developing independent management arrangements. Meanwhile, the international community has moved towards a binding agreement (e.g. Gollasch et al. 2007; Hewitt et al. 2009b).

Ballast water has been implicated as the vector most likely to be responsible for several high profile marine species invasions (e.g. Carlton 1985, 2001; Carlton & Geller 1993). Examples include:

- global increase in toxic dinoflagellate blooms (Hallegraeff 1993)
- introduction of the comb-jelly, *Mnemiopsis leidyi* into the Black, Azov and Caspian Seas, contributing to the collapse of the regions' anchovy fishery (e.g. Kideys 2002)
- dominance of the Asian clam, *Corbula* (*Potamocorbula*) *amurensis* in San Francisco Bay, California (Nichols et al. 1990)
- invasion of the northern Pacific seastar, *Asterias amurensis* into Hobart, Tasmania and Port Phillip Bay, Victoria (Ross et al. 2003).

The finalisation of a ballast water convention (BWM 2004) through the United Nation's International Maritime Organization, which followed more than 14 years of negotiations (Gollasch et al. 2007; Hewitt et al. 2009a, b), has resulted in a refocus on the potential for biofouling to transport species (e.g. Hewitt et al. 2009b, c).

Biofouling has long been recognised as an introduction mechanism for marine and estuarine organisms (e.g. Carlton 1979; Carlton & Hodder 1995) and is increasingly being identified as an equal, if not greater, risk than ballast water during the past decade (e.g. Hewitt et al. 1999, 2004; Thresher 2000; Gollasch 2002; Hewitt 2002, 2003; Lewis et al. 2003, 2004; Minchin 2006, 2007; Schaffelke et al. 2006; Schaffelke & Hewitt 2007; Hewitt & Campbell 2010).

The introduction of *Mytilopsis sallei* into Darwin Harbour in 1999, followed by *Perna viridis* and *Hydroides sanctaecrucis* in Cairns (Trinity Inlet), drew attention to the fact that Australia was exposed to marine pests through biofouling. This was despite the fact that five years earlier Clapin and Evans (1995) had clearly identified that *Sabella spallanzanii's* entry into Australia was linked to biofouling. Furthermore, the evaluation of Port Phillip Bay (Hewitt et al. 1999, 2004) had determined that more than 78% of species were likely to have been introduced with biofouling.

Despite increasing awareness of these transport mechanisms, our knowledge base is limited, resulting in the need for decision support tools that provide consistency and transparency during decision-making.

Risk-based decision frameworks for the management of ballast water-mediated introductions have been under development since the mid-1990s. The implementation of these Decision Support Systems (DSS) has demonstrated the utility of risk analysis in the field of marine biosecurity. Application to biofouling, however, has been slow.

Risk analysis is commonly used for management of such issues because pragmatic decisions can be made that provide a balance between competing environmental and socio-economic interests, despite limited availability of information (e.g. Hayes & Hewitt 1998; Campbell 2005, 2007, 2008, 2009; Hayes et al. 2005; Hewitt et al. 2006; Barry et al. 2008; Campbell & Hewitt 2008a).

In a marine biosecurity context, conventional risk assessment methodology consists of five steps: identifying endpoints, identifying hazards, determining likelihood, determining consequences and calculating risk. This process is similar (following the five-step process) to the official risk management standard (AS/NZ4360:2004) used in Australia and New Zealand (Standards Australia 2000, 2004). Here we present an evaluation of the species-level risks associated with biofouling on vessels entering Australian waters, with a view to determining risk of entry, establishment and subsequent domestic spread.

[2] See <www.marinepests.gov.au> for further information.

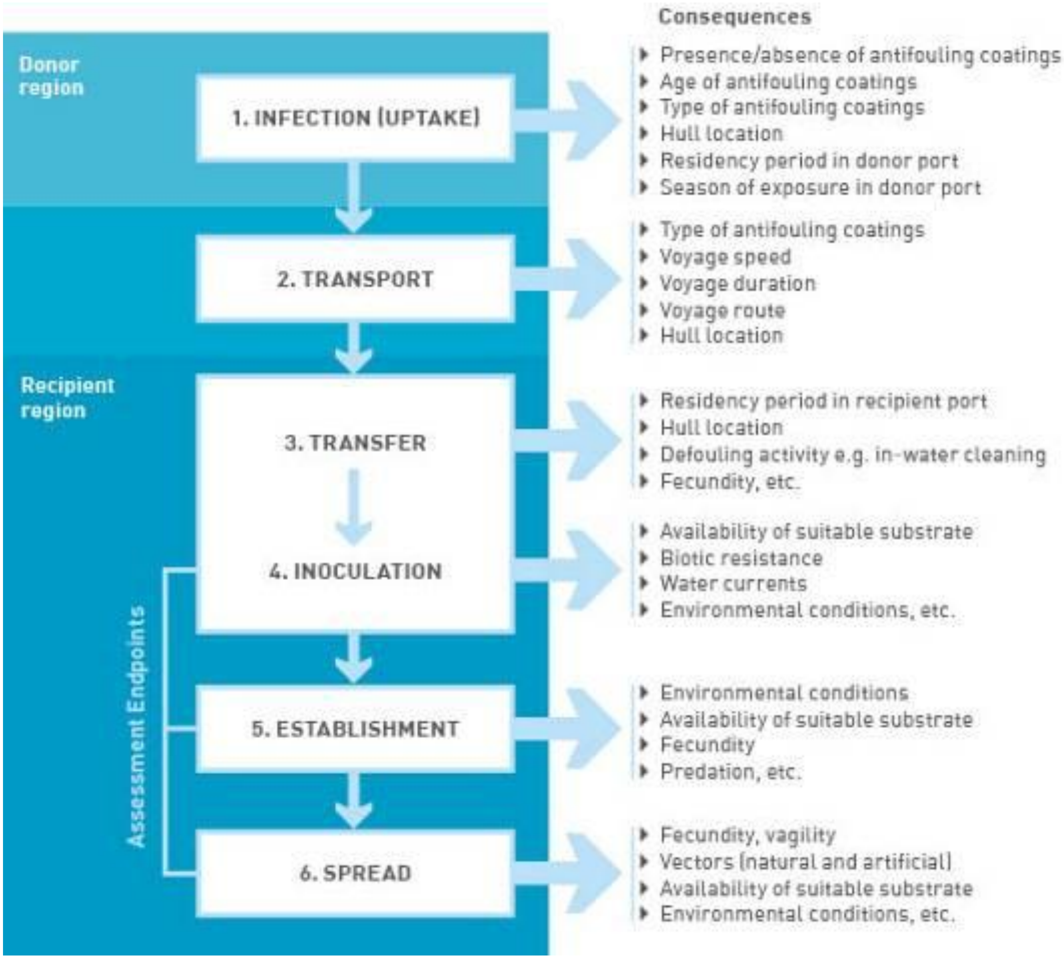
2.0 Methods and results

This risk assessment followed a five-step process: identify endpoints, identify hazards, determine consequences, determine likelihood and calculate risk (*sensu* Standards Australia 2000, 2004). It evaluated risk across three identified endpoints: inoculation, establishment and spread (see Figure 1).

This risk assessment focused on international vessels entering Australia, examining their international voyages prior to entry into Australia between 2002 and 2007 to determine the species likely to be transported. This data range was the most recently available when the analysis was undertaken and the period for which information on the majority of vessel types was available. Earlier records were unable to be used due to inconsistencies and cost constraints. In addition, the continuing domestic movements were assessed to determine the potential for further spread within Australia (see Section 2.3.3). Data about non-indigenous marine and estuarine species world-wide from the Hewitt & Campbell (2010) report was used as a starting point to identify hazards (i.e. species associated with biofouling). Other vectors, such as ballast water, aquaculture and aquarium trade, exist, which can facilitate transport of non-native species. Such vectors have been examined elsewhere (e.g. Hayes et al. 2005); this report specifically focuses on those hazards likely to be associated with biofouling.

Global non-indigenous marine and estuarine species were categorised as hazards based on their: association with biofouling, potential to arrive and establish in Australia and potential to cause impact.

Figure 1: Conceptual model of the species invasion process and contributing factors (adapted from Lewis & Coutts 2010).



Consequences (impacts) were assessed against the following four core values (modified from Campbell 2008) and a number of subcategories.

- Environmental–biological and physical characteristics of an ecosystem being assessed, excluding extractive use and aesthetic value. In this report, we have assessed consequences against impacts on habitat, biodiversity, trophic interactions, nationally important and ecologically valuable species, and assets of environmental significance.
- Economic–components within an ecosystem that provide a current or potential economic gain or loss.
- Social and cultural–values placed on a location in relation to human use for pleasure, aesthetic and 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. In this report, we have assessed consequences against impacts to social, cultural, aesthetic and national image.
- Human health–value of a safe and healthy society shared equally across generations and socio-economic groups.

To ensure a consistent approach, consequences were assessed using a number of different consequence matrices (see Appendix A) that gauge impact against: duration of impact (days/months/years); resilience (ability to recover); and scale/extent of impact (local, national and/or international). Threshold values within each consequence matrix were established via a number of expert workshops held in New Zealand, Australia and South America during previous research (e.g. Campbell 2005, 2008; Campbell & Gallagher 2007). The basis for the threshold values was derived from legislative and policy obligations in the first instance and subsequently adjusted through expert consultation (see Campbell 2005, 2007, 2008). Threshold values are based on consensus and represent a perceived value rather than a fixed value.

The likelihood (probability) of inoculation, establishment and spread of non-indigenous marine species was assessed using a likelihood matrix (see Table 3). Further descriptions of these stages are illustrated with examples within Section 2.3 of this document. A species risk can be derived once hazards are identified, and consequence and likelihood determined. A risk matrix (see Table 9) is used for this calculation. For example, a species that has a very low consequence ranking and a moderate likelihood of occurrence will result in a moderate risk ranking.

2.1 Identifying endpoints

The endpoint of the risk analysis is a critical stage in scoping the context of the assessment and determines the detail of consequence analysis to be applied (e.g. Campbell et al. 2007; Campbell 2008). For example, unintentional introductions of non-indigenous marine species associated with the movements of species, feed stocks and equipment would typically consider quarantine endpoints–that is, any unpermitted breach of the border (e.g. Hewitt & Hayes 2001, 2002; Hayes 2002; Campbell et al. 2007; Campbell 2009). Marine biosecurity risk can be evaluated across three endpoints:

- inoculation (or entry)
- establishment
- spread.

This risk assessment focuses primarily on the international entry of vessels (inoculation endpoint) with less extensive evaluations of establishment and spread.

2.2 Pest categorisation

2.2.1 Identifying hazards

Hazards have been defined in this context as non-indigenous marine species that:

- are associated with biofouling
- have potential to transcend the Australian quarantine border
- have demonstrated or inferred potential to cause a negative impact.

The identification of species-level hazards is based on the comprehensive assessment of recognised world-wide marine and estuarine invasions undertaken by Hewitt & Campbell (2010), which built on previous work by Hayes et al. (2004a).

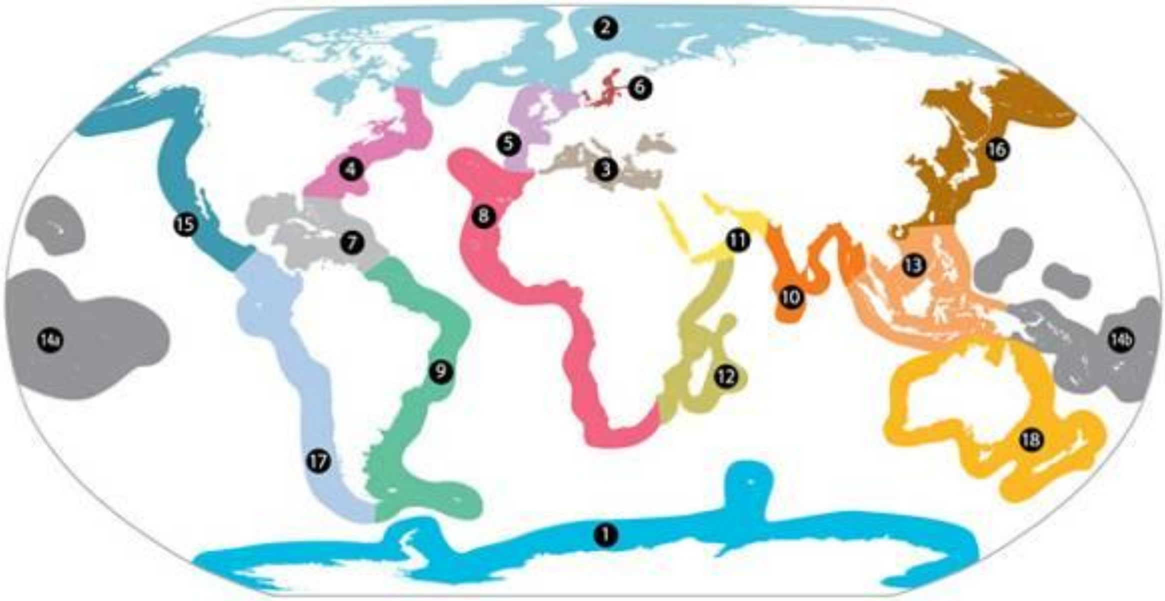
Hewitt & Campbell (2010) compiled information from over 700 data sources, including:

- primary literature (i.e. peer-reviewed journals and books)
- secondary literature (i.e. 'grey' literature such as websites, policy documents, online databases and reports)
- information derived from a number of researchers.

The global species distribution data was recorded using the 18 large-scale World Conservation Union (IUCN) marine bioregions (Kelleher et al. [1995] identified in Hewitt & Campbell [2010]). These are considered closer representatives of widely accepted biological provinces and offer a more conservative approach to estimating distributions than the finer scale ecoregions of Spalding et al. (2007), which do not represent provincial boundaries.

The designation and use of biogeographic boundaries has engendered significant debate in the literature, however, the use of provinces with recognition of overlapping boundaries provides the basis for the

Figure 2: The 18 IUCN bioregions (as defined by Kelleher et al. [1995] and modified following Hewitt et al. [2002]).



1 – Antarctica; 2 – Arctic; 3 – Mediterranean (including the Black and Azov Seas); 4 – North West Atlantic (including region 19 – North American Great Lakes); 5 – North East Atlantic; 6 – Baltic; 7 – Wider Caribbean Sea; 8 – West Africa; 9 – South Atlantic; 10 – Central Indian Ocean; 11 – Arabian Seas; 12 – East Africa; 13 – East Asian Seas; 14a&b – South Pacific (including Hawaii); 15 – North East Pacific; 16 – North West Pacific; 17 – South East Pacific; and 18 – Australia and New Zealand.

Kelleher et al. (1995) designation (Figure 2). This system creates a sequence of 'core' and 'transitional' areas, which are roughly equivalent to the Spalding et al. (2007) 'ecoregions' used by Molnar et al. (2008). Hayes et al. (2004a) used these 'core' and 'transitional' areas described by Kelleher et al. (1995) in their identification of 'next pests'.

By recording species at the bioregion level, it is assumed that the species is present in all ports in the bioregion. Due to limitations of the data available from many parts of the world, and the rapidity with which species can be transported within a region, this assumption avoids an overly restrictive data collection exercise.

The database of global marine and estuarine introductions developed in Hewitt & Campbell (2010) includes 1781 species–43 of which are restricted to lower salinities (<5 ppt). More than 98% of the 1781 species were allocated to possible transport vectors. This followed the criteria and methods proposed by Hewitt & Campbell (2010) which was similar to the evaluation of Port Phillip Bay in Hewitt et al. (1999, 2004) and was based on:

- examination of life history characteristics (at the species-level where available)
- morphological characteristics
- habitat associations.

Where species-level information was not readily available, genus-level characteristics were used to classify morphological characteristics and habitat associations.

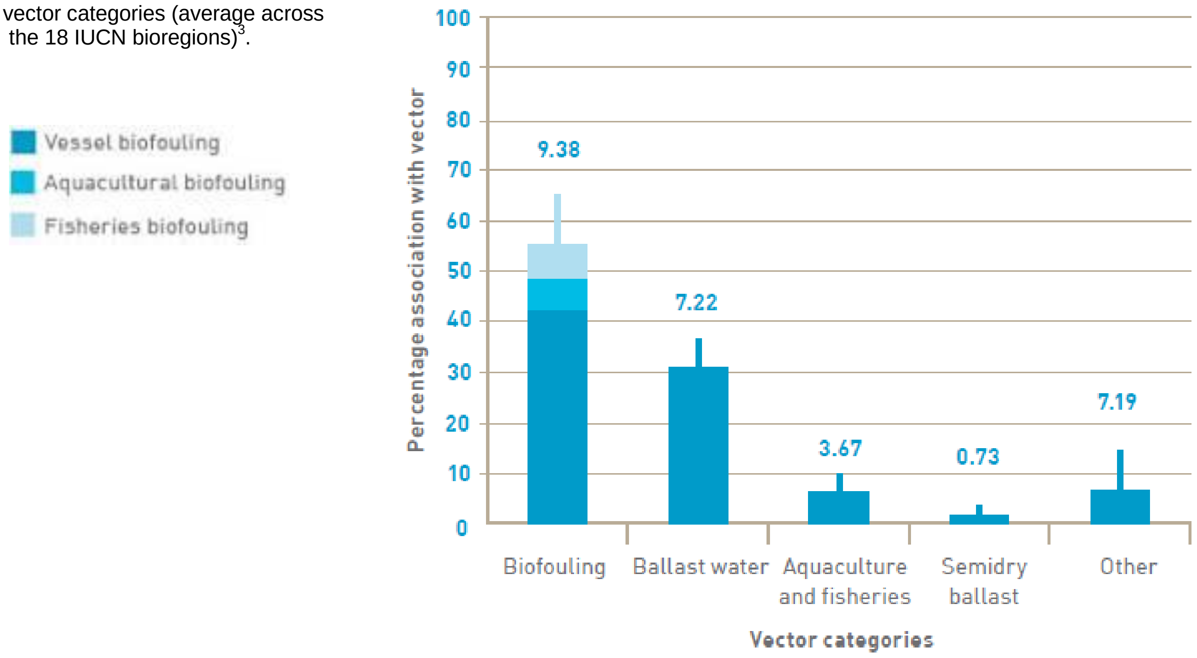
The global dataset indicates that more species have life history characteristics associated with vessel biofouling than any other vector (Figure 3), with vessel biofouling representing 42.6% (±2.2% SD) and total biofouling (vessel, aquaculture and fisheries) 55.5% (±9.4% SD). This represents a total of 793 species that have:

- a demonstrable invasion history at some location
- life history characteristics that infer an association with biofouling.

This species dataset was restricted further on the basis of records of species in Australia, resulting in a reduction to 657 species that:

- have an invasive history
- have an association with biofouling based on life history characteristics or statements in the literature
- are not currently known to be present in Australia.

Figure 3: Potential association for species to be transported by major vector categories (average across the 18 IUCN bioregions)[3].



[3] Average percentage of species in each of the 18 IUCN bioregions with potential to be transported by major vector categories. Standard deviations of the mean for each vector are presented by error bars and numbers above the line (Hewitt & Campbell 2010).

2.2.2 Determining consequences

Consequence rankings reflect the likely severity of impacts a hazardous event can create. In this context, it reflects the impact that a non-indigenous marine species can potentially have on the wide range of values the biosecurity system is attempting to protect. This section of the report evaluates consequences for four core values:

- environmental
- social and cultural
- economic
- human health.

In marine biosecurity, a semi-quantitative approach is typically used to capture stakeholder and expert perceptions, which are combined with available quantitative data. Quantitative (numerical) risk assessments are not common in a management context (although see Hayes & Hewitt 1998, 2000; Hewitt & Hayes 2001, 2002; Barry et al. 2008) because the data requirements are onerous, especially considering that little information is available about the impacts of many introduced marine species. Also, numerical risk produces numbers that are often treated as absolute judgements, which may lead to socio-political alterations in risk perception (Byrd & Cothern 2005).

Hayes et al. (2004a) states that there is currently no universally accepted way to measure the potential impact of non-native species. A variety of methods have been employed to develop more objective means of determining potential impact, including the heuristic assessment of expert opinions (Hayes & Sliwa 2003; Hayes et al. 2004a; Campbell 2008), stakeholder perceptions (Campbell 2008, 2009), and assessment of direct empirical evaluations from other regions (International Council for the Exploration of the Seas [ICES] 1984, 1988, 2005; Hayes & Hewitt 1998, 2000; Campbell 2008).

In order to improve consistency and aid stakeholder and expert discussion, consequence matrices have been developed across core values (i.e. environmental, economic, social/cultural, and human health) that explicitly delineate rankings of impact (consequence) from negligible to extreme (Campbell et al. 2007; Campbell 2008; Hewitt et al. 2006; Campbell & Hewitt 2008a; see Appendix A). These matrices provide exemplars of impact at the various ranks to provide guidance in predicting level of impact. Each primary category (environmental, economic, social/cultural, and human health) is divided into subcategories for more detailed consideration (see Table 2).

The readily accessible primary and secondary literature was evaluated for the 657 species. Using the consequence exemplars in the matrices (see Appendix A) the literature was assessed for records to identify demonstrable or inferred impacts across the four core values.

A total of 162 species (see Appendix B) had either inferred or demonstrated impacts, with environmental impacts the most frequently cited, followed by economic consequences. A large proportion of species with identified environmental impacts also had economic, social/cultural or human health effects (see Figure 4).

Table 2: Core value sub-categories for consideration in consequence matrices.

- **Environmental**
  - Habitat impacts from non-indigenous marine species
  - Biodiversity impacts from non-indigenous marine species
  - Trophic interaction (ecosystem) impacts from non-indigenous marine species
  - Nationally important and ecologically valuable species impacts from non-indigenous marine species
- **Economic impacts from non-indigenous marine species**
- **Social/cultural impacts from non-indigenous marine species**
  - Cultural impacts from non-indigenous marine species
  - National image impacts from non-indigenous marine species
  - Aesthetic impacts from non-indigenous marine species
- **Human health impacts from non-indigenous marine species**

For the remaining 495 species, there was no information available about their impacts–these are not assessed further in this report as explained below.

Based on the outcome of the literature evaluation, 162 species were deemed to be species of concern requiring a more thorough evaluation to categorise consequence using the agreed consequence matrices. The categorisation of consequence for the 162 species relied on the information from the literature, however, an indication of the severity of impact was often lacking. This resulted in use of the consequence matrices (see Appendix A) as guides to assign consequence ranks based on the severity of impact described in the literature, coupled with information about the spatial and temporal scale of impact.

Within the literature, impacts were either demonstrated, inferred, or 'missing'. Species for which no information relating to their impact could be found, were unable to be assessed further and were assigned a rank of 'negligible'. Demonstrated impacts ranged from negligible to extreme, whereas inferred impacts were generally restricted to ranks up to moderate to reflect the uncertainty involved. Exceptions included inferred impacts that have significant national and international implications. Such inferred impacts were categorised as high and this was relevant for impacts on:

- international and national obligations, including protected, threatened or endangered species or habitats (e.g. designated wetlands, habitat-forming species, cetaceans, mangroves, seagrasses, corals, sea fans)
- economic interests of national concern (e.g. high profile or migratory fisheries stocks, aquaculture stocks, tourism-related species)
- human mortality or morbidity.

Figure 5 illustrates the distribution of species' consequence rankings across environmental, economic, social/cultural and human health values. For the 495 species where no information on impact was found, an assignation of negligible was made. As a consequence, the lack of information for these 495 species resulted in these species not being considered further in this report. Regardless, a watching brief should be kept on these species in case significant impacts of species are documented.

Figure 4: Consequence information availability for species of concern across environmental, economic, social/cultural and human health values.

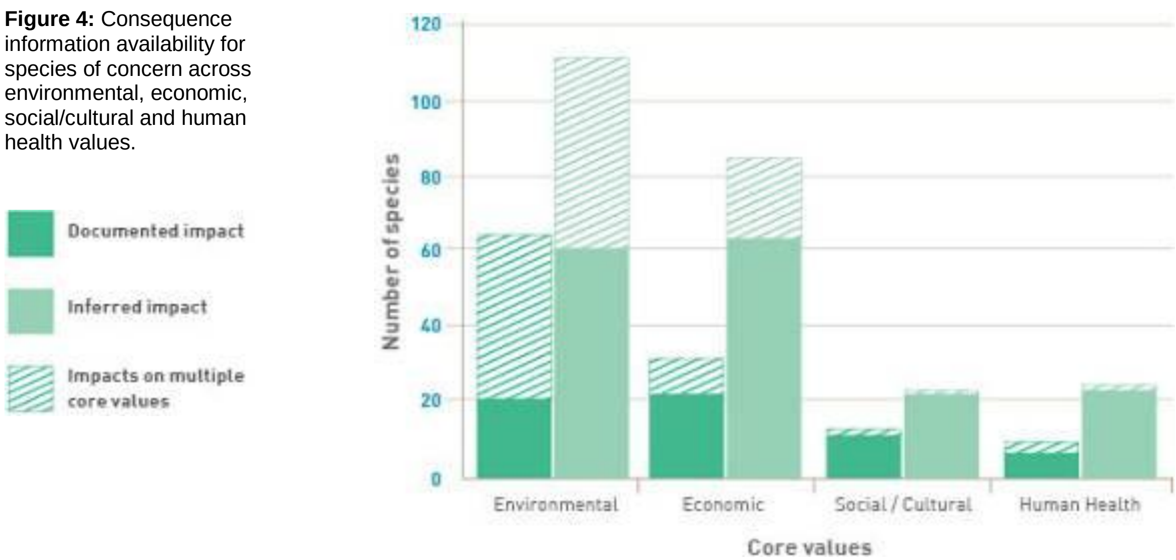
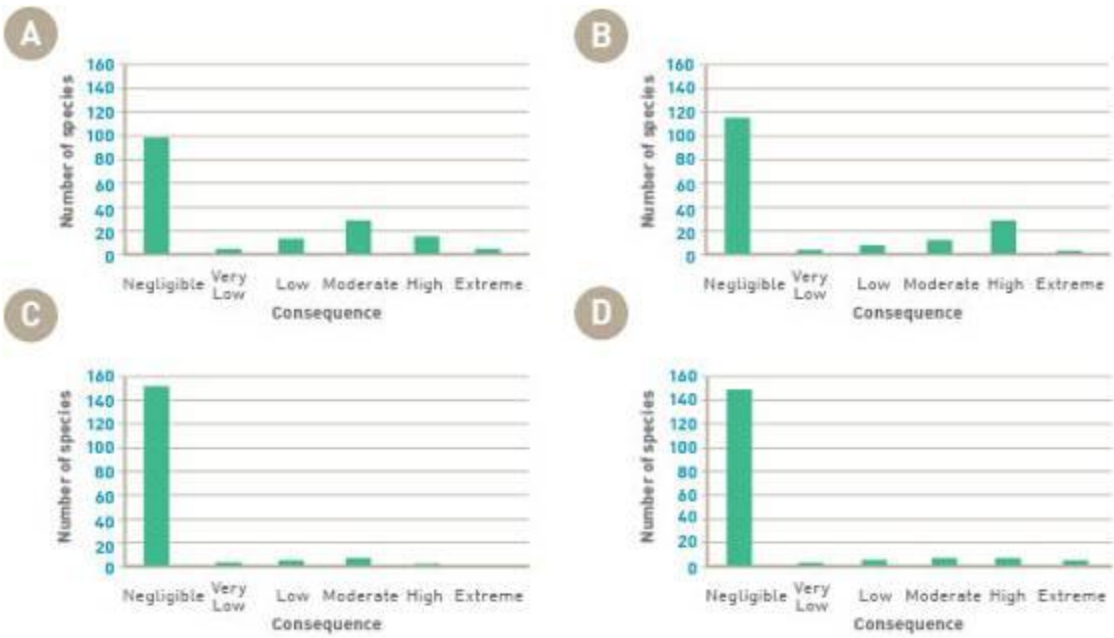


Figure 5: Frequency of species of concern with consequence rankings in the environmental (A), economic (B), social/cultural (C) and human health (D) values categories.



2.3 Determining likelihood

The likelihood (or probability) of an event occurring was determined using a likelihood matrix developed *a priori* (Table 3). This is an expansion (to include probabilities) on the standard likelihood matrix that has been used in marine biosecurity assessments in New Zealand (Campbell 2005, 2008, Campbell et al. accepted), Australia (Campbell & Hewitt 2008b) and the Mediterranean (Campbell et al. 2007). Three significant likelihood endpoints have been identified for evaluation of international biofouling species:

- inoculation
- establishment
- spread.

Table 3: Likelihood measures for marine biosecurity risk analysis (modified from Campbell & Gallagher 2007).

DESCRIPTOR	DESCRIPTION	PROBABILITY OF EVENT OCCURRING
Negligible (N)	The event is unlikely to occur	<1%
Extremely Low (EL)	The event will only occur in exceptional circumstances	1-10%
Very Low (VL)	The event could occur but not expected	10-25%
Low (L)	The event could occur	26-50%
Moderate (M)	The event will occur in many circumstances	51-75%
High (H)	The event will occur in most circumstances	76-100%

2.3.1 Inoculation

The likelihood of inoculation was evaluated using a matrix of likelihood rankings (see Table 4) that combines:

- association with biofouling (ranked negligible to high)
- transport pressure for each species (also ranked negligible to high) derived from:
    - settlement opportunity to colonise the vessel based on duration in overseas ports
    - the number of vessels arriving from regions where the species is present based on extended voyage characteristics
    - transport survival based on physical and physiological stress during the voyage
    - inoculation opportunity based on duration in an Australian port.

Table 4 provides a mechanism to combine the two elements of inoculation likelihood in a consistent and transparent fashion.

Several assumptions were made in this analysis, including:

- species were assumed to be able to attach or 'recruit' to a vessel at any time of year (equivalent to assuming reproductive activity throughout the year)
- species detected in a bioregion and reported in the literature were assumed to have established there (Note that data collection for species distributions ceased in May 2009)
- species detected in one location within a bioregion were assumed to be present in all areas (ports) of a bioregion
- vessels were assumed to have some areas without fully active antifouling coatings
- vessels were assumed to have some areas protected from the hydrodynamic forces created by vessel speed
- inoculum pressure was calculated for all of Australia, or for a particular province of Australia, rather than for a specific port
- all vessel categories were assumed to be equally able to transport all species
- all pathways from various bioregions to Australia were assumed equally 'stressful' (e.g. no influence of trans-equatorial transit).

Table 4: Matrix for ranking a species' inoculation likelihood based on biofouling association and transport pressure rank.

	Biofouling association: NEGLIGIBLE	EXTREMELY LOW	VERY LOW	LOW	MODERATE	HIGH
NEGLIGIBLE (N)	N	EL	EL	VL	VL	VL
EXTREMELY LOW (EL)	EL	VL	VL	VL	L	L
VERY LOW (VL)	EL	VL	VL	L	L	L
LOW (L)	VL	VL	L	L	M	M
MODERATE (M)	VL	L	L	M	M	H
HIGH (H)	VL	L	L	M	H	H

2.3.1.1 Association with biofouling

The metrics used for ranking species' association with biofouling were based on life history characteristics and a literature review based on demonstration of association (see Table 5). Ranks were assigned to individual species by two of the authors (Coutts & Hewitt) and differences were reconciled by mutual agreement.

Of the 657 species considered, information about impact was available for only 162 species. Of the 162 species with available impact information:

- 10 species were identified as having a negligible biofouling association based on life histories
- 11 species were rated as having an extremely low biofouling association due to being planktonic but with benthic resting stages
- 18 were identified as having a very low biofouling association
- 123 were ranked as having a biofouling association ranking equal to or greater than low, i.e. low, moderate or high (see Figure 6a)

Table 5: Biofouling association rank with associated characteristics.

RANK		CHARACTERISTICS
1	Negligible	No direct association with biofouling; planktonic with no benthic phase
2	Extremely low	Planktonic with benthic resting stage
3	Very low	Benthic **sedentary**, nestling or infaunal; no attached life history stage with **assumed** association with biofouling
4	Low	Benthic **sedentary**, nestling or infaunal; tube-forming mobile species with **demonstrable** association with biofouling
5	Moderate	Benthic **sessile** life history phase with **assumed** association with biofouling
6	High	Benthic **sessile** species; attached life history phase with **demonstrable** association with biofouling

2.3.1.2 Transport pressure

Transport pressure was assessed on the following factors:

- opportunity for biofouling-associated species to settle on the vessel in the donor port
- transport frequency (number of opportunities for transport)
- a species' ability to survive the transport process
- inoculation opportunity for a species to depart the vessel and settle in the receiving port.

Similar to the analysis by Hayes et al. (2004a), this assessment assumes that the opportunity for biofouling organisms to be transported is directly correlated with the number of vessel visits from a region. In keeping with previous assessments (Hayes & Hewitt 1998, 2000; Hayes & Sliwa 2003; Hayes et al. 2004a; Barry et al. 2008) it also assumes that a species record in a bioregion is considered a demonstration of establishment throughout the bioregion, and that all ports in that bioregion are infected.

For the purposes of transport pressure the element of assessment is the vessel. Therefore, the demonstration of a species' likely presence on a vessel is the focus, rather than the abundance of a species on any individual vessel.

Analysis of vessel activity was initially based on the Australian Quarantine and Inspection Service (AQIS) pratique dataset for vessel arrivals from 2003 to 2007. This information provided patterns for last port of call for vessels travelling to Australian ports, however, it did not differentiate petroleum vessels within the commercial vessel category and nor did it include illegal foreign fishing vessels (IFFVs). Subsequently, these patterns were investigated in greater detail using additional datasets to cover all vessel categories: the Australian Fisheries Management Authority (AFMA) dataset for IFFV apprehensions during the period of 2002 to 2007; and the Lloyds Maritime Intelligence Unit dataset (hereafter Lloyds MIU dataset) representing commercial vessels, petroleum vessels, non-trading vessels, naval vessels, commercial fishing vessels and recreational vessels (>25 m) entering Australia from 2002 to 2007 and including the previous 10 ports of call and next 10 ports of call. This practically means that for some vessels, voyage histories could extend earlier than 1999 (e.g. for vessels entering Australia in January 2002) or into 2008 (when the Lloyds MIU reported data to the authors). The Lloyds MIU dataset allowed a further differentiation of vessel categories, including separating petroleum vessels from commercial (merchant) vessels, and identifying subcategories of non-trading vessels.

The Lloyds MIU dataset represents an accumulation of Port State reports and consequently required significant error-checking for overlapping voyage statistics. To reduce the overlapping voyage statistics in which individual vessels were represented in multiple records (i.e. locations) at the same time, records from earlier than 1999 were removed because consistency of reporting could not be verified. Negative values for transit duration between ports were also removed. In addition, poor spatial resolution such as designation of ports as 'Pacific Ocean', 'Australasia', and 'Southeast Asia' were assigned to IUCN bioregions where unequivocal, or removed from the dataset. These changes resulted in <5% removal rate for the entire dataset.

Vessels are not of a consistent size, nor do they 'behave' in an identical fashion (e.g. Carlton 1985, 1996, 2001; Hewitt et al. 1999, 2004; Ruiz et al. 2000; Gollasch 2002; Fofonoff et al. 2003; Minchin 2006). As a consequence, vessels were divided into a number of categories (and further subcategories where appropriate) to reflect the various management regimes and previously recognised differences in vessel activity (e.g. Ribera & Bouderesque 1995; Ruiz et al. 2000; Carlton 2001; Lewis et al. 2004; Floerl & Inglis 2005; Floerl et al. 2005; Minchin 2006; Hulme 2009). These classifications are assumed to approximately correspond to vessel behaviours (e.g. maintenance history, voyage characteristics, speed [see Figure 16]), however, it has been assumed here that no particular vessel characteristic is more or less likely to transport a species.

Vessel categories used in this report include (also see glossary):

- **commercial vessels**, including merchant vessels and cruise ships
- **petroleum production and exploratory industry vessels**, including offshore anchor handling/support/supply; pipe laying vessels; drilling platforms/ships and floating production; storage and offloading (FPSO), given they are solely employed within the sector
- **naval vessels** (both foreign and domestic), including naval auxiliary tankers
- **non-trading vessels** which encompass a wide variety of vessel types, including the subcategories of tugs, research vessels, dredges, barges and yachts >25 m or superyachts (differentiated based on differing behaviours including speed, duration in port, and voyage characteristics)
- **fishing vessels**, including 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
- **illegal foreign fishing vessels** (IFFVs) which are differentiated from commercial fishing vessels due to behaviours and different regulatory controls
- **recreational vessels** which incorporate yachts <25 m length due to regulatory controls in Australia.

As stated above, petroleum industry vessels represent a significant class of commercial (merchant) vessel with widely varying characteristics, including long residence times and slow speeds for some vessel types. Original analysis of the AQIS pratique dataset found that it provided insufficient information to differentiate petroleum vessels from other vessels within the commercial vessel category. Subsequently, obtaining the Lloyds MIU dataset allowed further differentiation of vessel categories, including separating petroleum vessels from commercial (merchant) vessels, and identifying subcategories of non-trading vessels.

The three datasets (Lloyds MIU; AQIS pratique; AFMA) were interrogated to identify the number of unique vessel entries into Australia based on the vessel categories (see Figure 7). The Lloyds MIU dataset was interrogated to determine the relative contribution across vessel categories for all of Australia and for each of the four primary Australian provinces (see Figure 8).

Elements of transport pressure are further analysed below.

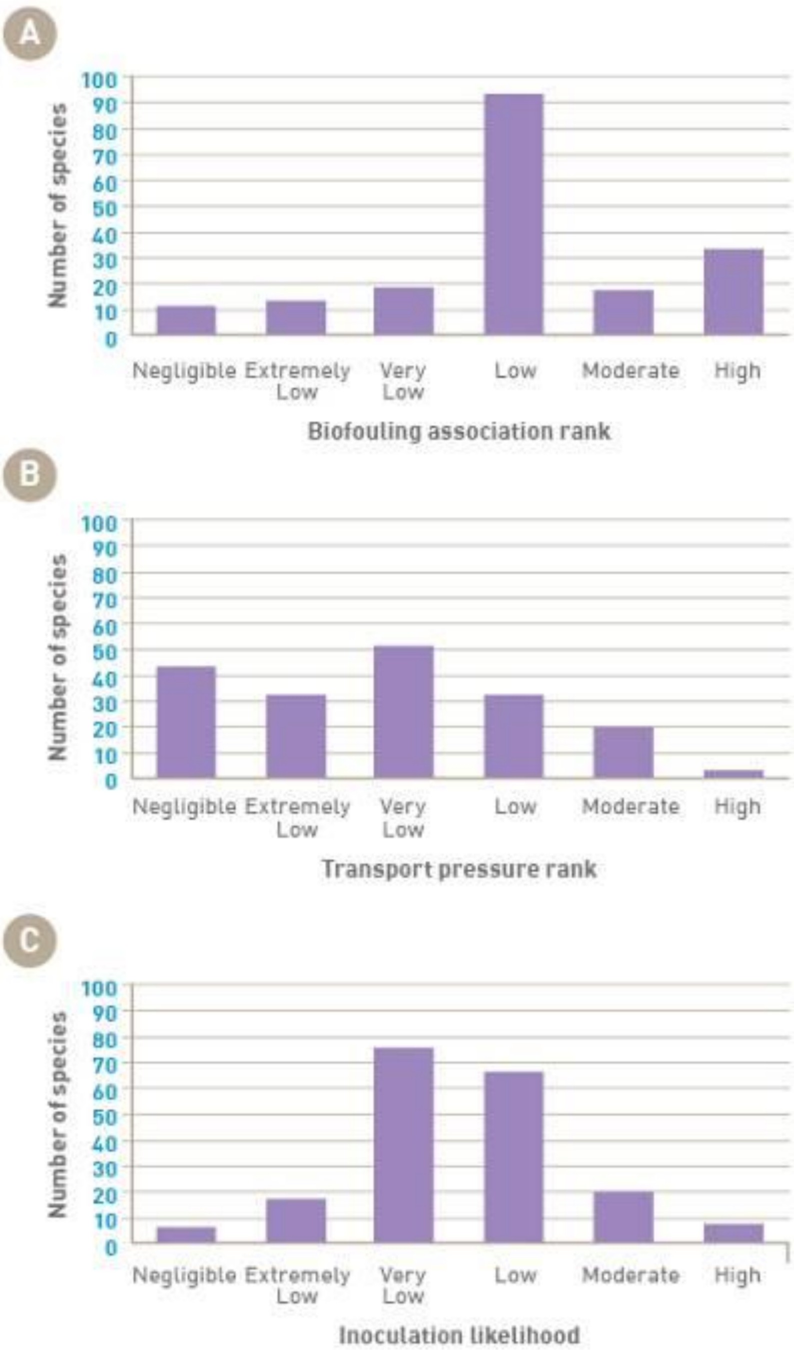
Opportunity to infect the vessel in the donor port

The opportunity for a species to infect (i.e. settle on or recruit to) a vessel depends on a combination of factors, including: the stage of biofouling currently present; maintenance history (including antifouling paint condition); whether the timing of the opportunity coincides with an active reproduction period for sessile and sedentary species; and the amount of time available for a species to settle or colonise.

Biofouling community development begins as soon as materials are placed in the water (e.g. Sutherland & Karlson 1977; Floerl 2002). As a consequence, shortly after vessels are cleaned–in dry-dock or in the water–the settlement of marine organisms and development of a biofouling community begins (see Hayes et al. 2004b; Lewis et al. 2004). The rate of this development can be reset or delayed through various means, including in-water cleaning and appropriate application of antifouling paints. However, when the vessel is considered as a whole, the ‘niche’ biofouling areas including sea-chests, bow and stern thrusters, propellers, propeller shafts and rudder areas are likely to have secondary or tertiary levels of biofouling shortly after (three to six months) cleaning or antifouling paint application (e.g. James & Hayden 2000; Floerl 2002; Hayes 2002; Coutts et al. 2003; Coutts & Taylor 2004; Hayes et al. 2004b; Lewis et al. 2004; Piola et al. 2009). Therefore, few limitations to settlement exist for any individual species when considering the vessel as a whole, hence all vessels can be colonised.

Settlement opportunities for some species also involve an element of timing. Mobile species associated with biofouling have the ability to swim to the vessel hull or into niche areas; therefore, no restriction on the timing of settlement occurs. For species that are sessile or sedentary, typical means of establishing in a new location are either by accidentally getting ‘swept’ to another location by hydrodynamic forces (e.g. waves, propeller wash, currents), or by reproduction. Many sessile or sedentary marine species spawn gametes (reproductive elements) into the water column where fertilisation and development occurs, or hatch larvae directly into the water column–these species are known as meroplankton since they spend a portion of their life cycle in the water column. Once development has progressed sufficiently–ranging from minutes to months for different species–the larval form is able to settle onto hard substrate by metamorphosing into an adult.

Figure 6: Likelihood ranks for **(A)** biofouling association, **(B)** transport pressure and **(C)** inoculation likelihood using the matrix in Table 4. Transport pressure here, is based on last port of call only. Data from Lloyds MIU dataset.



In order for a meroplanktonic species to settle on a vessel, it is necessary that the species' timing of reproduction (reproductive phenology) and settling periods for planktonic phases to coincide with the duration in port. Assessing settlement opportunity would require a significant increase in our current state of knowledge–there is limited data on the timing or triggers (cues) of reproduction for many non-indigenous marine species, particularly in introduced regions. This is particularly important as non-indigenous marine species expand on their realised niche to utilise their fundamental niche and hence they often behave in ways that are not recorded within the literature. For example, *Mytilopsis sallei* in Darwin Harbour produced two, potentially three, cohorts in a seven-month period (Campbell & Hewitt, unpubl. manuscript). In Hong Kong Harbour, where M. sallei is also introduced, it produces two cohorts per 12 months (Morton 1989); however, in its native environment M. sallei reproduces once every 12 to 18 months (Kalyanasundaram 1975). Similarly, the larval durations and metamorphosis requirements have yet to be determined for many introduced species.

Given that settlement opportunity acts to reduce risk, it is more conservative to assume that all species reproduce year-round and therefore, have the ability to inoculate any vessel that comes to port. As more information emerges, or when the focus is reduced to a smaller subset of species, better life history information can be obtained and applied in a management context.

In order to estimate the amount of time a species has to settle on an individual vessel, the mean (± SD) and cumulative duration in port were calculated for each IUCN bioregion based on vessel port visits between 2002 and 2007 (Lloyds MIU dataset), noting that this captures neither recreational vessels <25 m nor IFFVs.

As stated above, most vessels will already have secondary or tertiary levels of biofouling in some area, therefore port duration will represent an **increased** opportunity of settlement. In order to account for greater likelihood of species settling on the hull of vessels with longer duration in ports, a weighting function ('opportunity to infect') was developed and applied to the number of vessel visits for each vessel category within a bioregion (see Table 6).

Figure 7: Number of unique vessels (by vessel category) entering Australia between 2002 and 2007. (Lloyds MIU dataset, AQIS pratique dataset and Australian Fisheries Management Authority [AFMA] IFFV dataset).

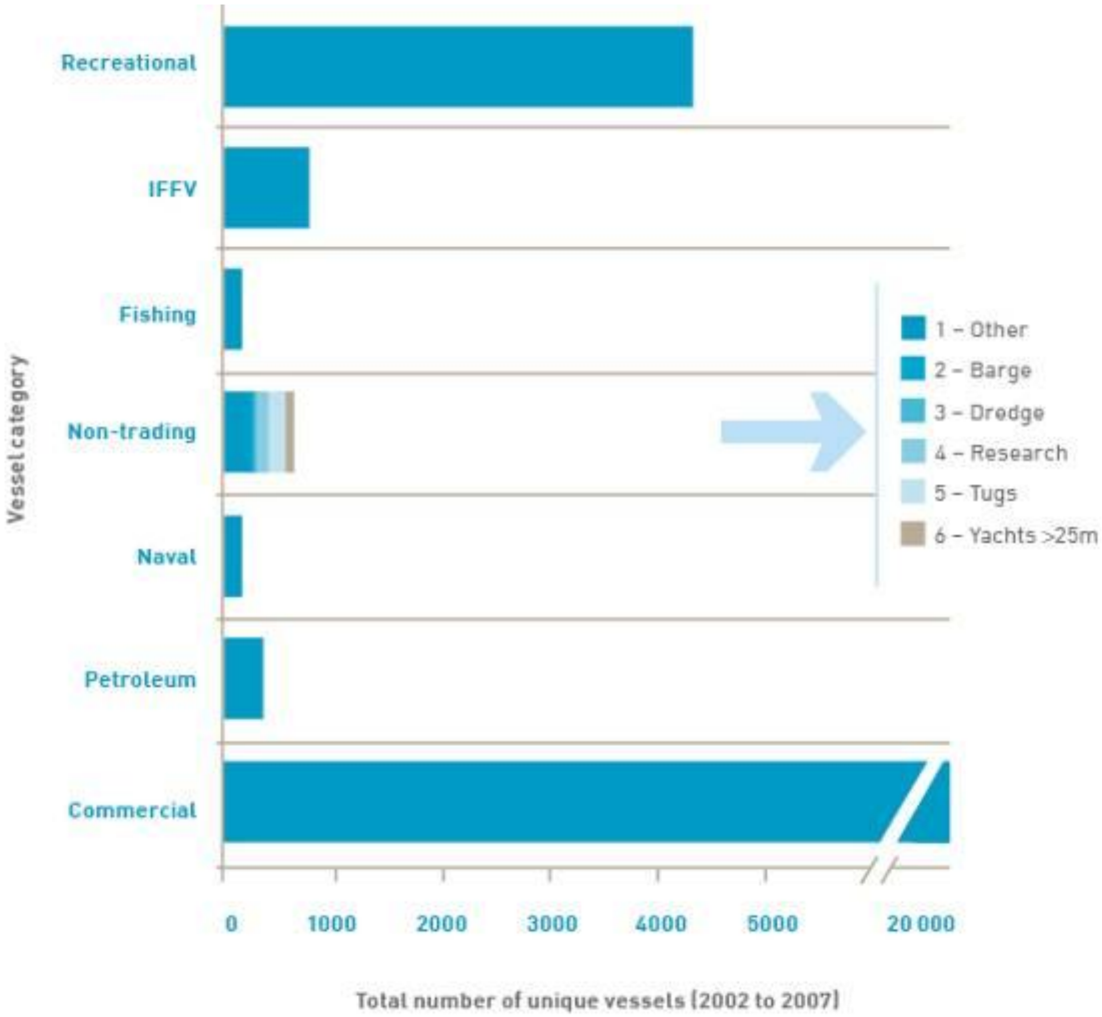


Figure 8: Major marine bioregeographical provinces of Australia.

Solanderian – tropical

Peronian (includes Lord Howe and Norfolk Islands)- warm temperate

Flindersian – cold temperate

Dampierian (includes Cocos, Keeling and Thursday Islands and Ashmore Reff)- tropical. Provinces adjusted from Bennet and Pope (Knox

'Opportunity to infect' weightings were based on literature evaluations of biofouling accumulation (e.g. Sutherland & Karlson 1977; Carlton & Hodder 1995; Lewis 2002). Port stays greater than 20 days are likely to develop primary levels of biofouling and create enhanced opportunities for settlement and growth of individual secondary biofouling organisms. Port stays of greater duration (~30 days) increase the settlement and growth of secondary biofoulers; and port stays of >60 days increase the opportunities for tertiary biofouling (Carlton & Hodder 1995; Floerl 2002; Lewis et al. 2004; Floerl & Inglis 2005). Growth rates are contingent on ambient temperature and other factors (e.g. Sutherland & Karlson 1977). The weighting was calculated from the mean vessel duration in port, based on an assumption that greater numbers of days represent increased opportunity for species to infect. The weighting was arbitrarily constrained between one and two. However, this could readily be adjusted to increase the influence of port duration in the assessment.

Bioregions with greatest number of vessels clearly exhibit a greater accumulated time in port (see Figure 9a; see also Appendices D and E). The mean duration in port by vessel visit (see Figure 9b; see also Appendices D and E), however, demonstrates that vessel turnaround is comparable across most trading regions, with the obvious exception of the Antarctic (see Figure 9a and 9b).

As previously stated, recreational vessels <25 m and IFFVs are not captured by the Lloyds MIU dataset, but previous evaluations (e.g. Floerl 2002; Floerl & Inglis 2005; Floerl et al. 2005, 2009; Hayes et al. 2004a, b; Forrest et al. 2009) suggest that these categories of vessels will, on average, have longer port durations with stays reaching several years in extreme instances.

Table 6: Opportunity to infect settle weightings based on mean duration in port for all vessel transits between 2002 and 2007 (Lloyds MIU dataset).

RANK	WEIGHTING	CHARACTERISTIC
Negligible	1.00	Mean duration in port ≤2 days
Extremely Low	1.10	Mean duration in port >2 and ≤5 days
Very Low	1.25	Mean duration in port >5 and ≤20 days
Low	1.50	Mean duration in port >20 and ≤30 days
Moderate	1.75	Mean duration in port >30 and ≤60 days
High	2.00	Mean duration in port >60 days

Transport frequency

The number of vessel entries arriving from each bioregion (last port of call) from 2002 to 2007 was calculated as a total across all vessel categories and for each individual vessel category. For each of the 162 species, the number of vessels arriving from bioregions in which the species was known to be present–either as a native, cryptogenic or a non-indigenous marine species based on the Hewitt & Campbell (2010) database–was calculated to represent the raw transport frequency of each species. This figure represents the potential opportunities that the given species had to be transported into Australian waters over the five-year period based on last port of call.

Vessels are likely to accumulate species since their last cleaning (including in-water cleaning, dry-docking or antifouling paint application), however, this data is infrequently available for evaluation. Most commercial vessels have dry-docking rotations of greater than three years and up to five years (Lewis 2002; Davidson et al. 2009). With a number of Australian states banning in-water cleaning for larger vessels (ANZECC 1997), the period between cleaning is likely to exceed several years. The influence of voyage duration on species accumulation was assessed by creating voyages into classes of 30, 60, 90, 183 and 365 days prior to entry into Australia.

During shorter 'voyages', the majority of vessels transited between one or two bioregions. Only a few vessels visited three or more bioregions during a 30-day period (see Figure 10a). As voyage time increased, however, a greater number of bioregions were visited by vessels. After 90 days, a relatively large number of vessels were visiting three bioregions (illustrated by the 'hump' in Figure 10c); and after 183 days, a second 'hump' was evident in the graph, showing a significant number of vessels visiting six bioregions (see Figure 10d). This accumulation of bioregions over voyages of longer duration is demonstrated by an increase in the mean number of bioregions visited on voyages of longer duration (see Figure 11). On average, vessels visited at least two bioregions within a six-month period (183 days). These voyage durations were used to evaluate the changing transport pressure and subsequent inoculation likelihood (see Figure 12a and b, respectively).

Between 2002 and 2007, Australia had approximately 15 000 international vessel (including recreational vessels <25 m and apprehended IFFVs) entries per year and the fleet traded with all global bioregions at some point (during that period).

Transport patterns differed between bioregions (see Figure 13) and changed over time (see Appendix C: Figures C1 to C6), showing an increase in trade from the North West Pacific and East Asian Seas and moderate decreases in other regions. The increase in transport frequency from bioregions as voyage durations increased from 30 days to 365 days can be seen with the addition of lighter shades of grey. As would be expected, more distant bioregions such as the Arctic, North West and North East Atlantic, Baltic and the Mediterranean are largely represented in voyage lengths greater than 60 days.

The influence of recreational vessels <25 m and apprehended IFFVs is more restricted due to the lower numbers of vessel visits (see Figure 14) and the more seasonal nature of recreational vessel arrivals (see Figure 15). Both recreational vessels and IFFVs arrive from a differing suite of bioregions, creating a different risk profile from other vessel categories (see Figure 14).

Recreational vessels largely arrive from the South Pacific or East Asian Seas, although this represents their last port of call rather than their home port. Little information is available concerning the previous ports of call (or bioregions), however many recreational vessels (<25 m) transit through the South Pacific from North East Pacific, Wider Caribbean, and either North East Atlantic or North West Atlantic. This category of vessels is also likely to spend lengthy amounts of time in port at a variety of locations given that it is associated with recreational activities. The seasonal nature of arrivals in Australia is largely driven by cyclonic activity, resulting in an arrival prior to storm season (e.g. cyclone and monsoon) and possibly increased port stays in Australia immediately after having arrived from overseas.

IFFVs largely arrive from the East Asian Seas and South Pacific and are apprehended by AFMA and impounded at one of several nearshore (or port) locations. While the numbers of vessel apprehensions have been consistent through time, a similar level cannot be assumed into the future.

Figure 9: Cumulative (A) and mean duration (B) of vessels' port stays in each of the 18 IUCN bioregions from 2002 to 2007 (Lloyds MIU dataset). Bars represent the mean number of days per year with one standard deviation (lines).

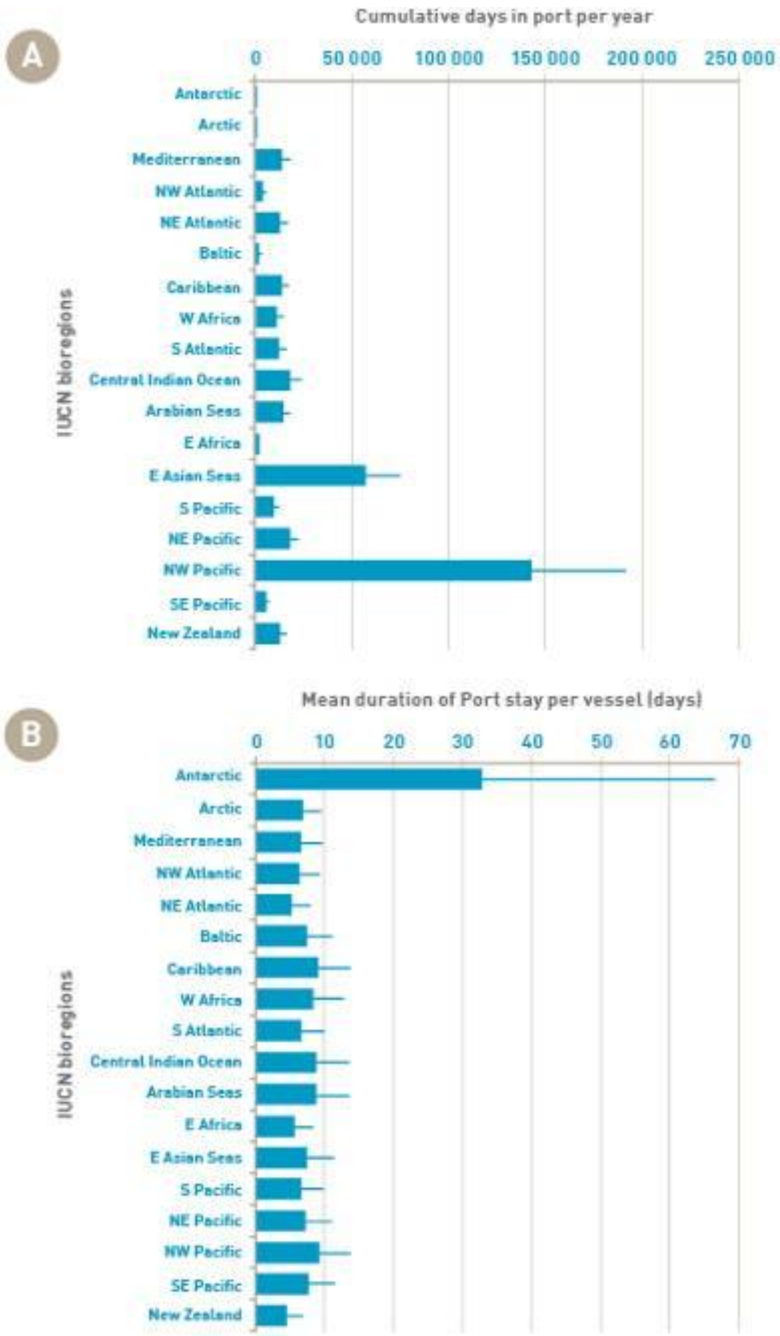


Figure 10: Number of IUCN bioregions transited by vessels for **(A)** 30-day, **(B)** 60-day, **(C)** 90-day, **(D)** 183-day and **(E)** 365-day voyages (derived from subsampling 2007 voyage data, Lloyds MIU dataset).

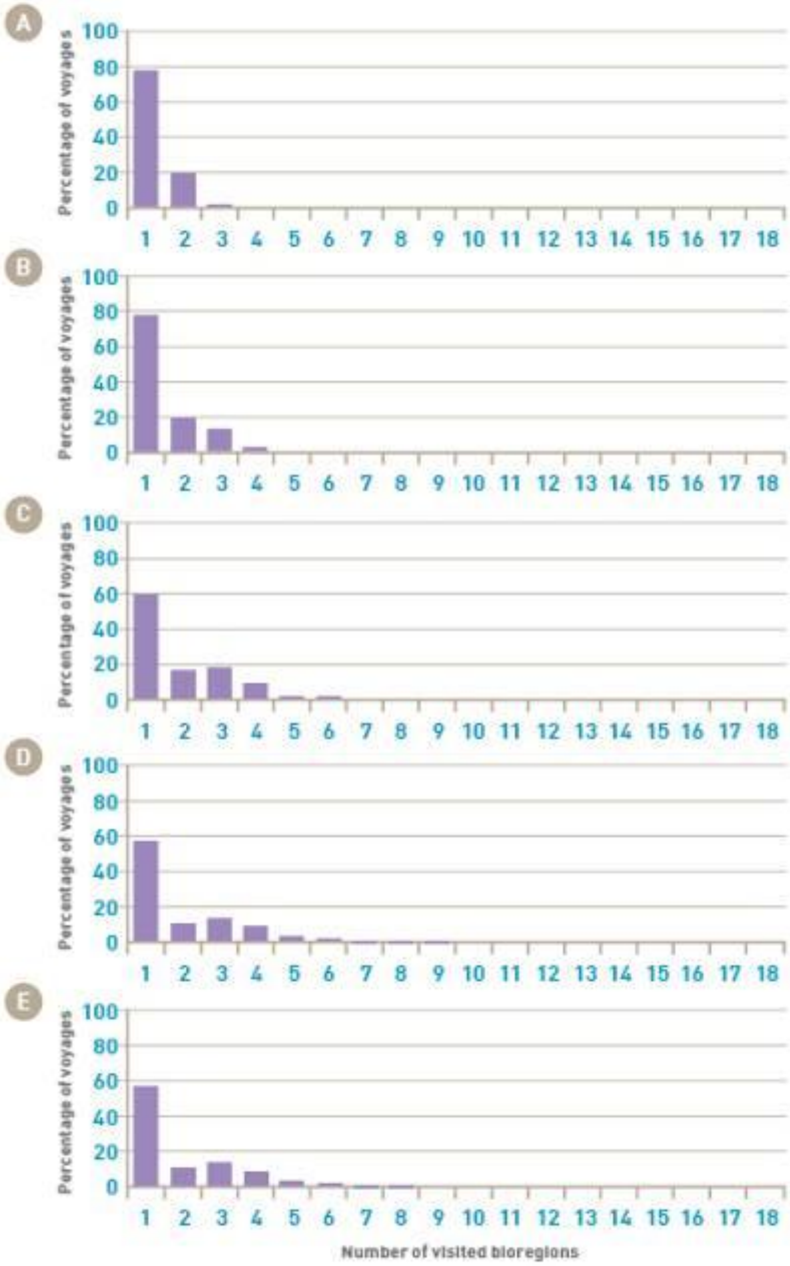


Figure 11: Mean number of bioregions visited with increasing voyage duration. Data from Lloyds MIU dataset.

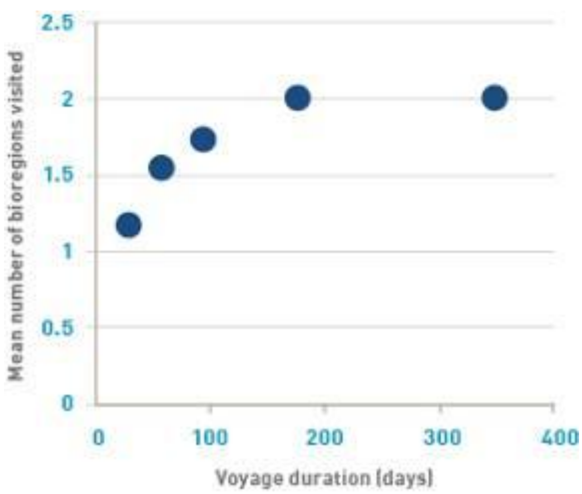


Figure 12: Transport pressure rank **(A)** and inoculation likelihood **(B)** for vessels that have been on voyages of 30, 60, 90, 183 and 365 days prior to entering into Australia. Data from Lloyds MIU dataset.

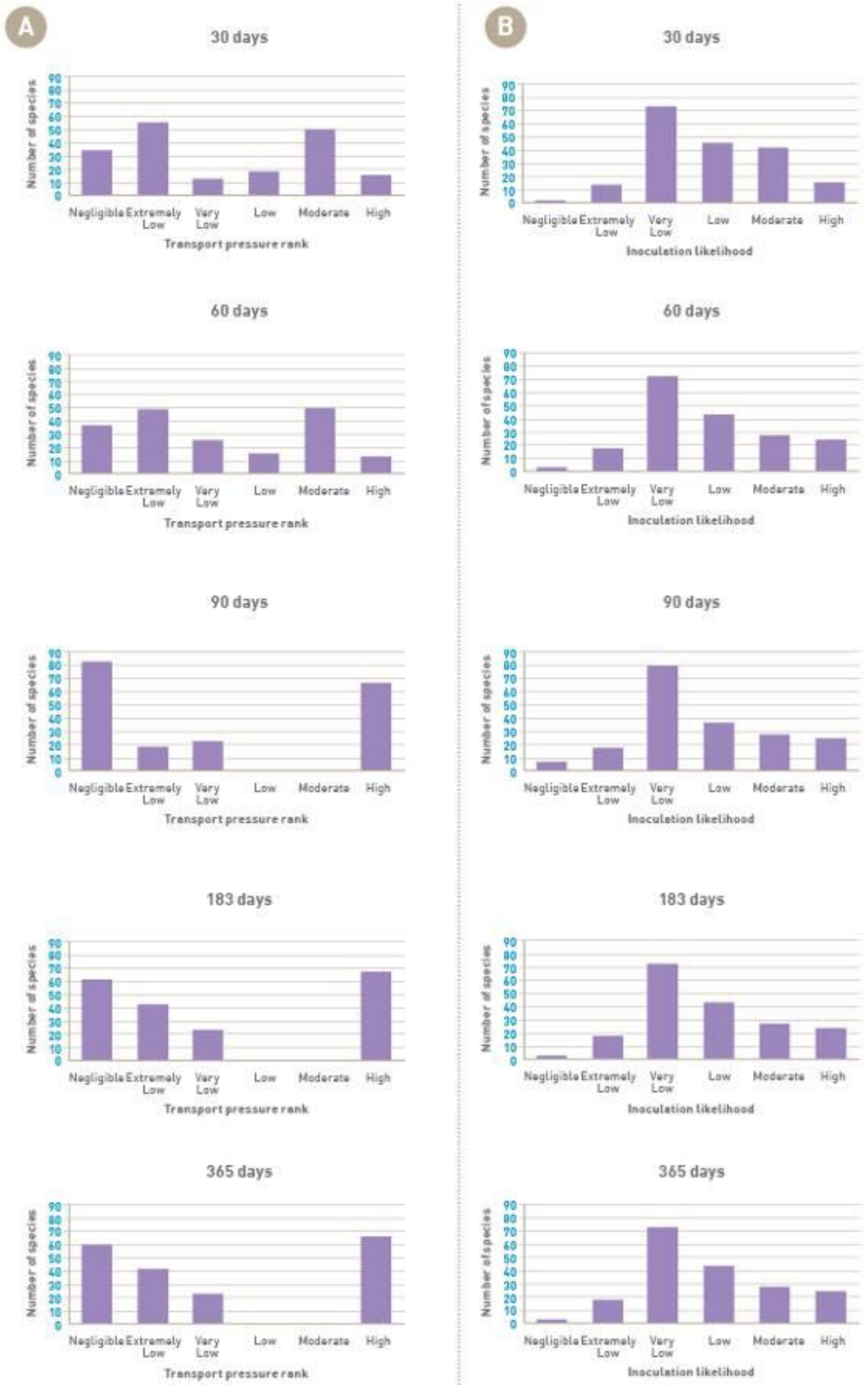


Figure 13: Number **(A)** and percentage **(B)** of vessels (all categories) that visited Australia from 2002 to 2007 which had traded with specific bioregions for 30, 60, 90, 183 or 365 days during that five-year period. Note that recreational vessels <25 m and IFFVs are presented only in the 30-day voyage period due to data constraints (Lloyds MIU dataset, AQIS pratique dataset and AFMA IFFV dataset).

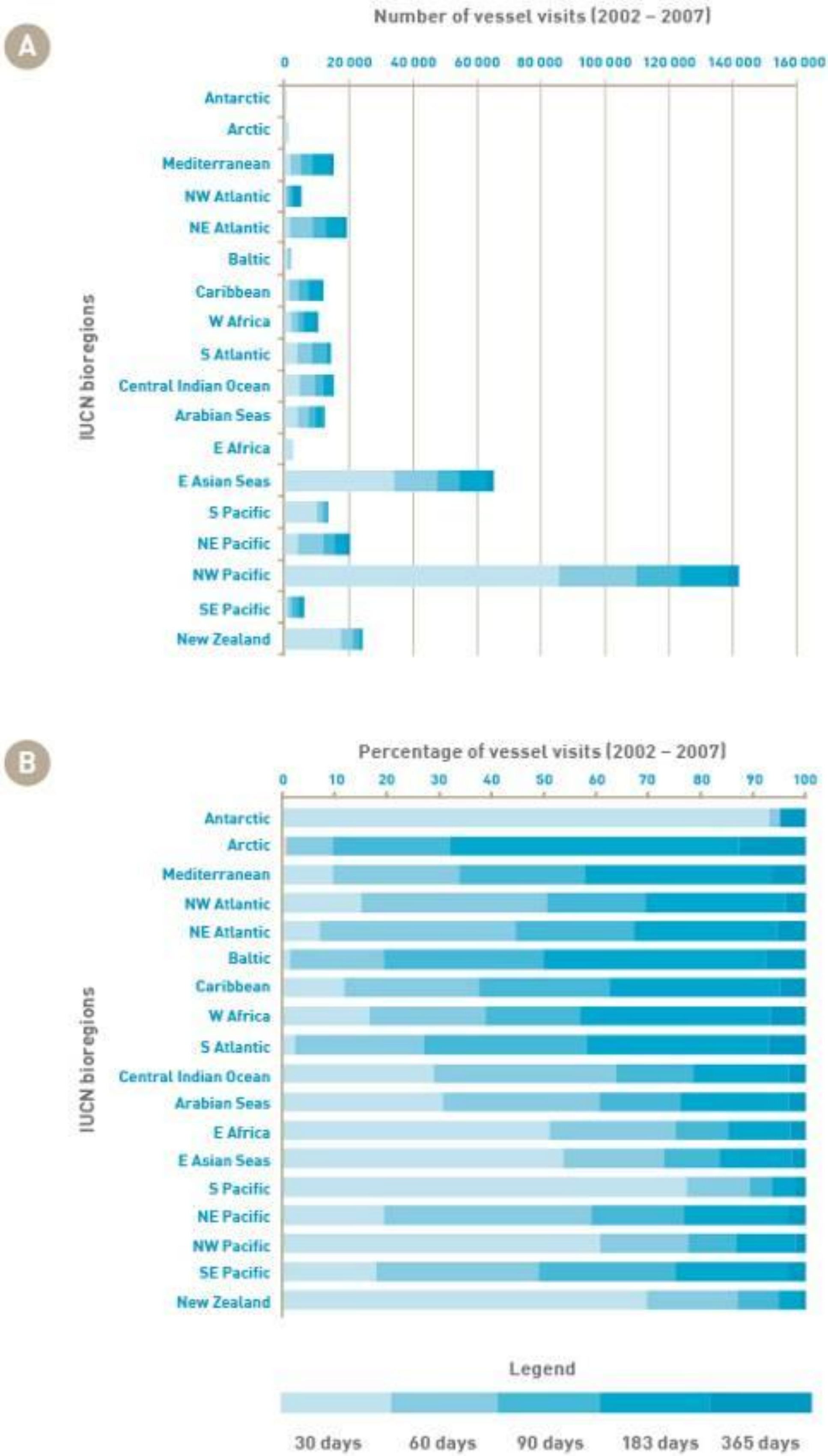


Figure 14: Mean number of recreational vessel visits per year **(A)** to Australia and apprehended IFFVs brought into Australian waters per year **(B)** between 2002 and 2007 (AQIS pratique dataset and AFMA IFFV dataset, respectively). Bars represent the mean number of days per year with one standard deviation (lines).

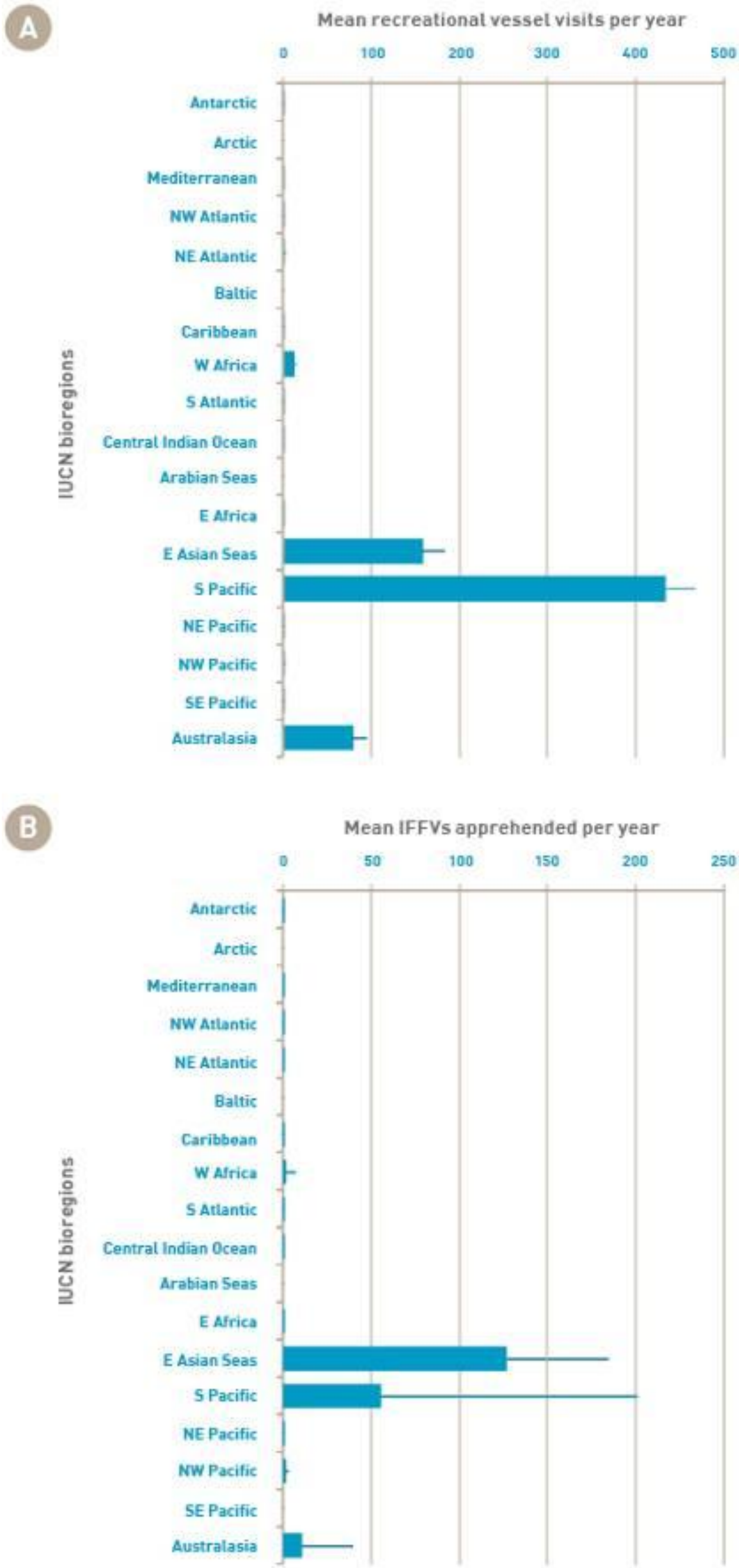
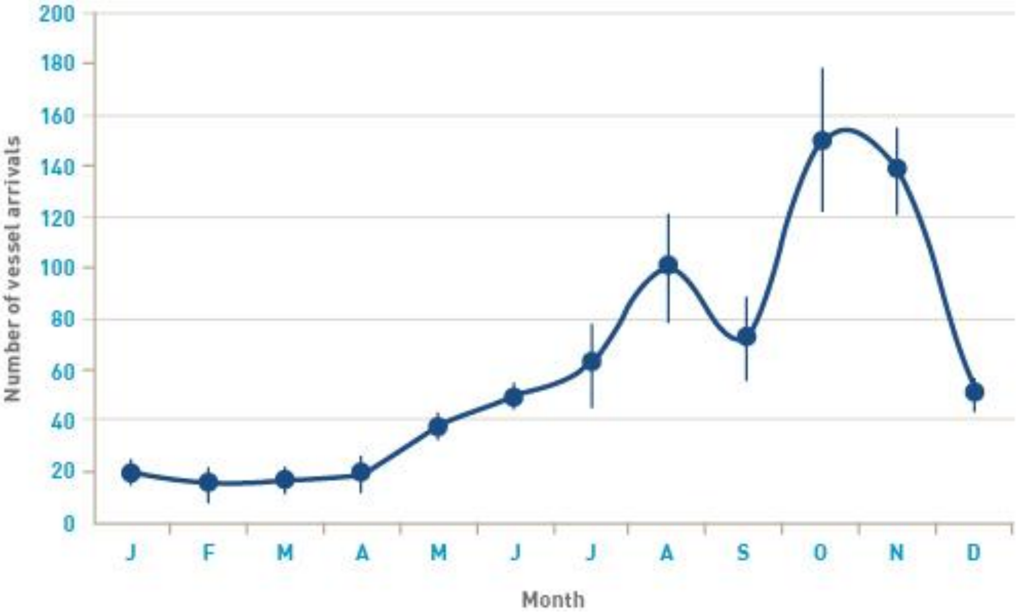


Figure 15: Average number of recreational vessel arrivals into Australia for each month between 2002 and 2007 (AQIS pratique dataset).



Transport survival

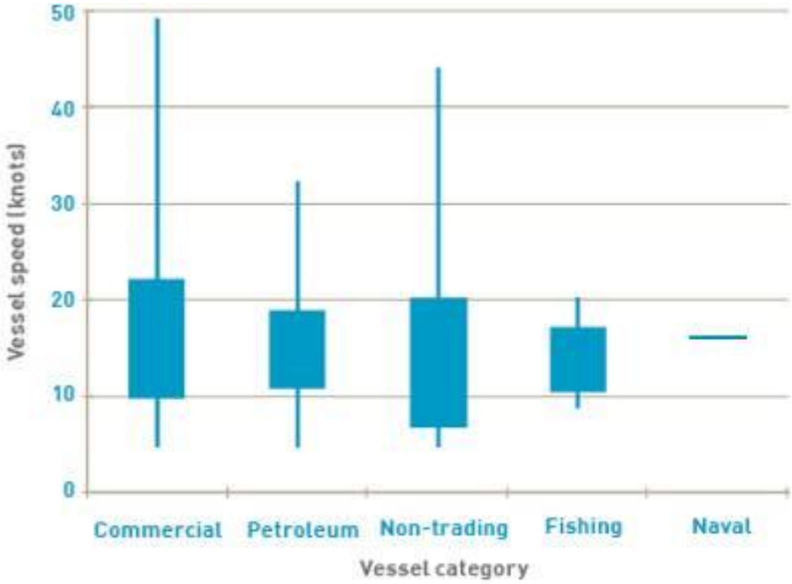
The transport process can create significant physical and physiological stresses on species that impacts their ability to survive a voyage.

Physical stress on species is primarily caused by vessel speed. Several studies have demonstrated the relationship between speed and shear stress on species survival (e.g. Coutts 1999; Davidson et al. 2009; Coutts et al. 2010). Analysing the Lloyds MIU dataset for vessel speeds across vessel categories (see Figure 16) revealed no significant differences across the broad vessel categories (excluding recreational vessels <25 m and IFFVs), despite significant differences between individual vessels within categories. Vessels in the categories of commercial, petroleum, non-trading (specifically tugs, barges and dredges), IFFVs and recreational vessels are known to travel at slow speeds– significantly increasing a species' likelihood of survival (e.g. Floerl & Inglis 2005; Floerl et al 2005; Davidson et al. 2009; Coutts et al. 2010).

Additionally, while vessel speed is correlated with species presence on exposed hull surfaces (e.g. Coutts et al. 2010), numerous protected niche areas such as sea-chests (e.g. Coutts et al. 2003; Coutts & Taylor 2004; Coutts & Dodgshun 2007), bow and stern thrusters, propellers and propeller shafts, will allow species to survive despite high vessel speeds (e.g. James & Hayden 2000; Hayes 2002; Coutts & Taylor 2004; Hayes et al. 2004b). As a consequence, speed may not provide differentiation between vessel types nor significantly reduce risk.

Physiological stress on species can be created by the type and condition of antifouling paints used on a vessel (e.g. Piola & Johnston 2006) as well as the voyage route. Antifouling paints are explicitly designed to minimise and delay the settlement of epibenthic species on the hull surface. There is extensive research detailing the efficacy and various failings of antifouling paints (e.g. Minchin 2006; Dafforn et al. 2008; see also various publications in the journal Biofouling). Most recently, the ban on organotin paints, specifically tributyltins (TBTs) has prompted investigations into viable alternatives and resurrected the concerns over biofouling-mediated invasions. Antifouling paints differ significantly in their effectiveness, as well as their method and location of application (Lewis 2002; Lewis et al. 2004; Piola et al. 2009). From a management perspective, information on antifouling paint type, application procedures and timing of application is difficult to obtain. As a result, the use of antifouling paint was not studied in this risk assessment.

Figure 16: Reported speeds of vessels (by category) entering Australia between 2002 and 2007. Maximum/minimum reported range indicated by line, 90% confidence intervals around the mean represented by blocks. Slow moving drill rigs and drill ships have been estimated to have a vessel speed of 5 knots and are included in with petroleum vessels; recreational vessels >25 m are included in non-trading vessels. Vessel speeds for IFFVs and recreational vessels <25 m could not be obtained. Data from the Lloyds MIU dataset for 2002 to 2007.



Physiological stress associated with exposure to changing environmental conditions is likely for biofouling species associated with the external hulls of vessels. Transport between high or mid-latitude regions on either side of the equator will expose species to the physiological stresses of increased water temperature during transit. Similarly, freshwater species in transit across oceanic barriers (e.g. between the North American Great Lakes and the inland waters of Europe) will fully experience marine waters during transit across the North Atlantic. Most trade routes to Australia entail a crossing of the equator, several of which may also be accompanied by a freshwater transit through the Panama Canal or a high salinity transit of the Suez Canal. Quantifying the effect of these transits is difficult without laboratory analyses of individual species' physiological tolerance and exposure. As this factor only acts to decrease the likelihood, leaving it out of the current assessment until definitive information is available, provides a conservative result. Therefore, we have assumed that all voyage pathways are equally stressful.

Inoculation opportunity

Similar to the opportunity for species to settle in the donor port, attached biofouling species need to either reproduce (sexually or asexually) or be scraped off the hull to inoculate a receiving port. Any sedentary, infaunal and mobile fauna associated with biofouling assemblages (e.g. gastropods, crabs and other mobile crustaceans, small fishes such as blennies and gobies, seastars), including those occurring in sea-chests, will have increased opportunity to leave the vessel either by being dislodged or by swimming or dropping off the vessel. Inoculation opportunity is typically believed to be a function of port duration and the reproductive maturity or vagility (ease of movement) of individual species.

As with the previous discussion, reproductive activity can be influenced by many factors including the intrinsic maturation rate of individuals, and extrinsic factors such as temperature and day length (Minchin & Gollasch 2003). These influences on reproduction can be as difficult to ascertain as in the donor ports (see 'Opportunity to settle on the vessel in the donor port' in Section 2.3.1). The action of being scraped off a hull is a stochastic process and depends on a number of elements, including the species' location on the hull, its attachment mode, type of antifouling coating on the vessel, and the handling of the vessel; in port. The vagility of sedentary and mobile fauna associated with biofouling is, by definition, high. These species are capable of moving and will therefore have the opportunity to leave the vessel at any time once in port. As a consequence, biofouling and biofouling-associated species were assumed to have the ability to reproduce (sexually or asexually), escape and/or swim away or be scraped off, all year-round.

Identifying the time available to inoculate a recipient port was calculated as the mean (± SD) and cumulative duration in Australian ports within each of the four biogeographic provinces (see Figure 17; see also Appendices D and E). Cumulative days in port inform the overall opportunity of species entry, but are indicative of species transport only, being heavily influenced by vessel traffic. Arguably, an individual attached to the hull of a single vessel that remains in port for the year is likely to have a greater opportunity to reproduce, be dislodged, or depart that vessel, than individuals on 365 different vessels arriving throughout the year for one day only. An individual attached to the hull of a single vessel for an entire year will experience the entire seasonal change in a new region, leading to the likelihood of reaching sexual maturity and attaining a size that would be susceptible to wave action or damage. In contrast, the mean (± SD) of individual vessel visits provides a more realistic indication of inoculation opportunity of individual species.

The Dampierian province (Cape Leeuwin, Western Australia to Cape York, Queensland) has the highest average for port duration, followed by the Solanderian (Eastern Queensland), however, the absence of data concerning oil rigs, IFFVs and recreational vessels <25 m is of concern. Such vessel types are known to have long residence periods and are able to transport non-indigenous marine species (Floerl 2002; Floerl & Inglis 2005; Floerl et al. 2005).

More than 89% of vessel arrivals in Australia are in the commercial category (see Table 7). For Australia as a whole, the North West Pacific followed by East Asian Seas and South Pacific were the highest vessel origins between 2002 and 2007 (see Figure 13; Appendix C), although recreational vessels <25 m and apprehended IFFVs (Figure 14) are largely derived from the South Pacific and East Asian Seas, respectively.

Significant differences in arrival patterns exist between Australian provinces in vessel number and origin (see Figures 18 and 19a-d; Table 7). The Dampierian province had the greatest number of vessel arrivals, followed by the Peronian, Solanderian and Flindersian provinces. The highest proportion of vessel arrivals in all four Australian provinces was from the North West Pacific IUCN bioregion in comparison to all other IUCN bioregions. The South Pacific had the highest representation of recreational vessels to all four regions, with the greatest number to the Solanderian province followed by the Peronian and Flindersian provinces. The East Asian Seas had the greatest contribution of all vessel types to the Dampierian province.

Figure 17: Vessels' cumulative **(A)** and mean duration **(B)** in ports within the four Australian provinces between 2002 and 2007 (+SD). Note that oil rigs, IFFVs and recreational vessels <25 m are not represented here (Lloyds MIU dataset).

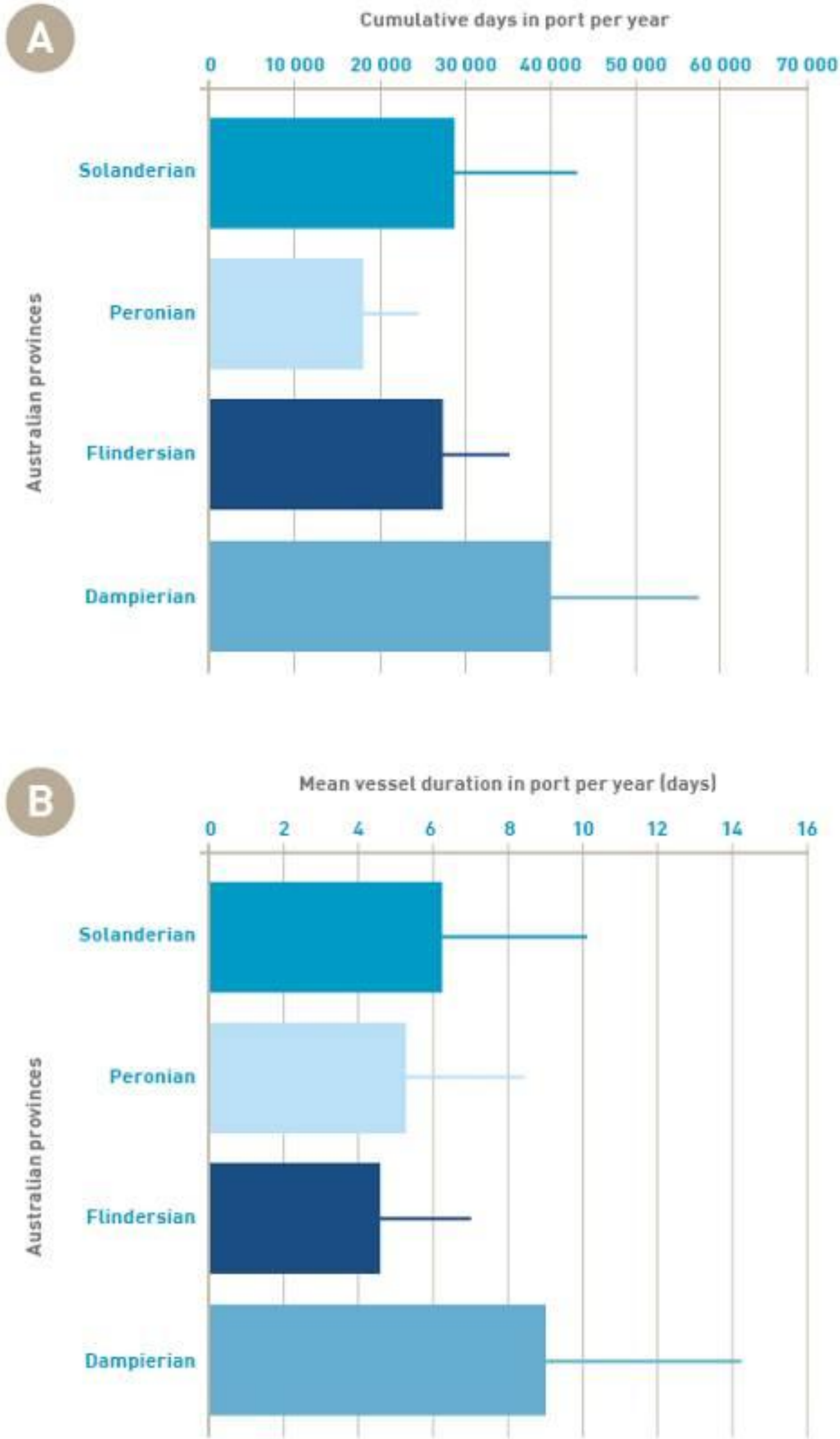


Table 7: Summary of vessel arrivals between 2003 and 2007 classified by IUCN bioregion of origin and vessel category (AQIS pratique dataset).

	COMMERCIAL VESSELS	NAVAL VESSELS	NON-TRADING	FISHING VESSELS	IFFVS	YACHTS
Antarctic	5	5	51	0	0	0
Arctic	1	0	0	0	0	0
Mediterranean	290	2	10	2	0	2
NW Atlantic	10	1	0	0	0	0
NE Atlantic	60	10	12	1	0	13
Baltic	3	0	0	0	0	0
Caribbean	134	0	6	0	0	1
W Africa	307	1	27	15	0	64
S Atlantic	45	0	0	0	0	2
Central Indian Ocean	479	24	10	0	0	6
Arabian Seas	1040	41	16	1	2	0
E Africa	504	7	7	17	2	6
E Asian Seas	12 824	178	633	109	897	377
S Pacific	3454	244	241	81	5	2678
NE Pacific	466	5	4	0	0	2
NW Pacific	31 266	33	151	35	12	5
SE Pacific	108	0	7	0	0	1
New Zealand	4101	64	138	35	5	428
TOTAL	**55 097**	**615**	**1313**	**296**	**923**	**3585**

Summary of transport pressure

To reiterate the various assumptions made when assessing transport pressure:

- species were assumed to be present in all areas (ports) of bioregions to which they had been introduced or were native
- all vessels were deemed to have an equal opportunity of a species settling, regardless of time of year or the period since dry-docking, in-water cleaning or antifouling paint application
- all transport pathways were considered to be equally stressful.

To determine a species' transport pressure, a series of calculation steps were undertaken. First, the numbers of arriving vessels in each category were calculated for each bioregion and multiplied by the port duration weighting (to take into account the opportunity for settlement). This number was then summed within each of the 18 bioregions. Then for each species, the weighted number of vessels arriving from all bioregions where the species was present (as a native, cryptogenic or non-indigenous population) 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. In order to account for effect of voyage duration, these steps were repeated for vessels visiting bioregions over 30-, 60-, 90-, 183- and 365-day voyage windows (see Figure 12).

These vessel numbers were then ranked according to likelihood probabilities in Table 3 to provide a categorical rank for each of the voyage periods as a function of percentage of total visits. As a result, a large number of species were identified as having a negligible transport pressure (ranging from 19% in 30 days to 32% in 365 days). In contrast, more than 35% of species were ranked as having low, moderate or high transport pressure across all voyage lengths (see Table 8).

Table 8: Percentage of species with transport pressure likelihood ranks for voyages of 30, 60, 90, 183 and 365 days (Lloyds MIU dataset).

TRANSPORT PRESSURE RANK	VOYAGE LENGTH				
	30 days	60 days	90 days	183 days	365 days
Negligible	19.0	19.5	44.3	31.9	31.9
Extremely low	29.7	25.9	9.2	21.6	21.6
Very low	6.5	13.5	11.4	11.4	11.4
Low	9.7	7.6	0.0	0.0	0.0
Moderate	27.0	27.0	0.0	0.0	0.0
High	8.1	6.5	35.1	35.1	35.1

2.3.1.3 Summary of inoculation likelihoods

Based on the biofouling association ranks (see Figure 6a) and transport pressure ranks (see Figure 6b), inoculation likelihood (see Figure 6c) was calculated using the matrix in Table 4.

More than a third (35%) of all species were identified as having an inoculation likelihood ranking of low, moderate or high (see Figure 6c), with an increasing percentage of species ranked in the high category for longer voyage timeframes (see Figure 12). As would be expected, increasing voyage duration captures a greater number of bioregions (see Figures 11, 12, 13), resulting in an increase in the pool of species and an increased capture of vessels with longer port stays.

2.3.2 Establishment

Establishment represents the survival and development of a self-sustaining population once a species has been inoculated into a new (receiving) environment (e.g. Occipinti-Ambrogi & Galil 2004). There is a common theory amongst researchers (e.g. Carlton 1985; Lodge 1993; Ruiz et al. 2000; Hewitt & Huxel 2002; Lockwood et al. 2007) that a species' likelihood of establishment is related to its invasion and inoculation characteristics as well as the traits of the receiving environment.

Species characteristics which influence establishment likelihood include physiological tolerance to the new (receiving) environment sufficient for reproduction to occur and all life history stages to survive. These are typically based on empirical evaluations of species' tolerances to a suite of environmental factors, such as temperature, salinity, light and dissolved oxygen. However, these empirical evaluations have been carried out for a relatively small number of species (e.g. Hayes & Hewitt 1998, 2000; Campbell 2009).

Given these constraints, a second method of estimating a species' probable survival in a new region is to match the environmental characteristics of the donor region where it is known to exist, with a recipient region–a process known as environmental matching (e.g. Hilliard & Raaymakers 1997; Kilroy et al. 2008; see also Hewitt & Hayes 2001, 2002). As Barry et al. (2008) suggest, evidence to support the utility of environmental matching in the marine environment is limited, largely due to the inappropriate selection of environmental characteristics and scale by various authors. The ability for environmental matching to provide realistic risk evaluations becomes increasingly limited as nonsensical or irrelevant environmental factors are included in the analysis (Barry et al. 2008).

One of the greatest errors in environmental matching assessments is the inappropriate use of scale. As Hewitt & Hayes (2002) demonstrate, environmental matching is meant to create a surrogate measure for the species of concern's tolerance range. This is done by selecting a location where a species is known to exist (the donor location), and using a range of environmental values to compare with a potential recipient location. If the donor location is restricted to a port, rather than the entire province or bioregion in which the species resides, then an artificial limit to the range of environmental values will be derived. To illustrate this, Hewitt and Hayes (2002) demonstrated that the temperature ranges of the Port of Sydney and the Port of Hobart differ and hence, based on a simple environmental match, species would not be expected to survive in both. Regardless, Sydney and Hobart are located within a single large-scale province and share many species. For example, when the two ports' temperature ranges are compared with the temperature tolerances of the introduced seastar, *Asterias amurensis*, they both fall well within the range of its survival (Hewitt & Hayes 2002).

Figure 18: Vessel arrivals from 2003 to 2007 categorised by trading region (based on last port of call IUCN bioregion) and the province through which they entered Australian waters (see Figure 8; AQIS pratique dataset).

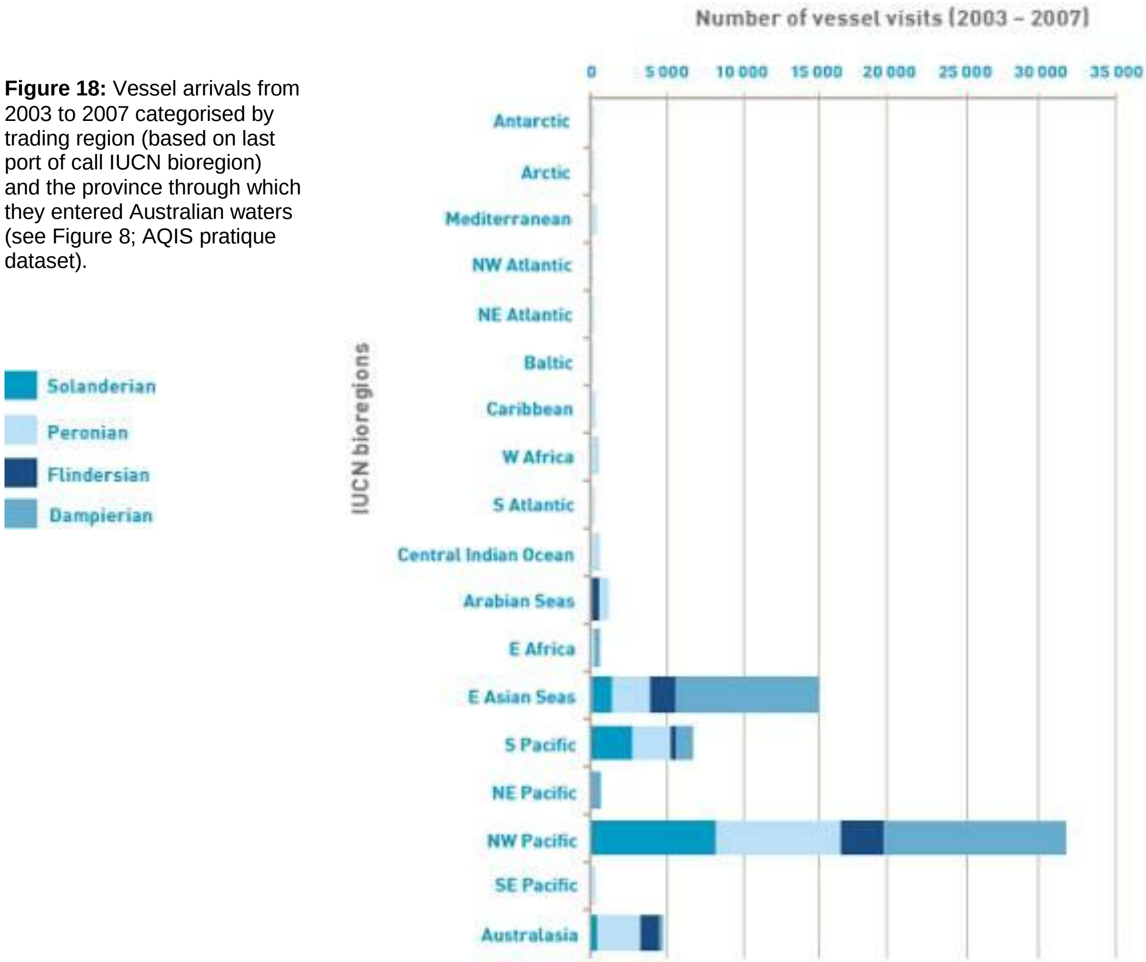
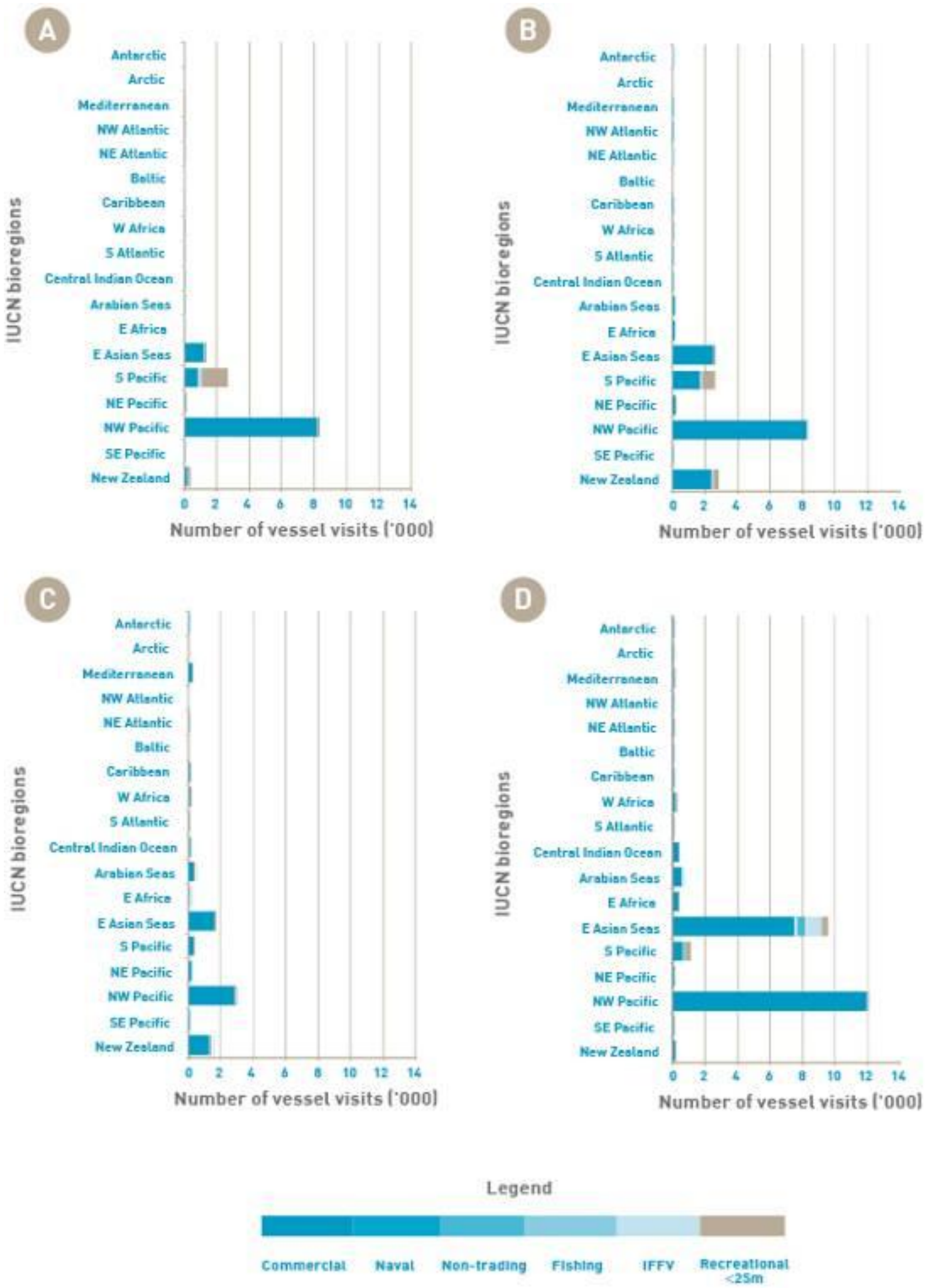


Figure 19: Vessel arrivals to each Australian province between 2003 and 2007 categorised by vessel type and trading region (based on last port of call IUCN bioregion). The four Australian provinces are: **(A)** Solanderian province, **(B)** Peronian province, **(C)** Flindersian province, and **(D)** Dampierian province. Note that petroleum vessels are included in commercial vessels due to the constraints of the AQIS pratique dataset.

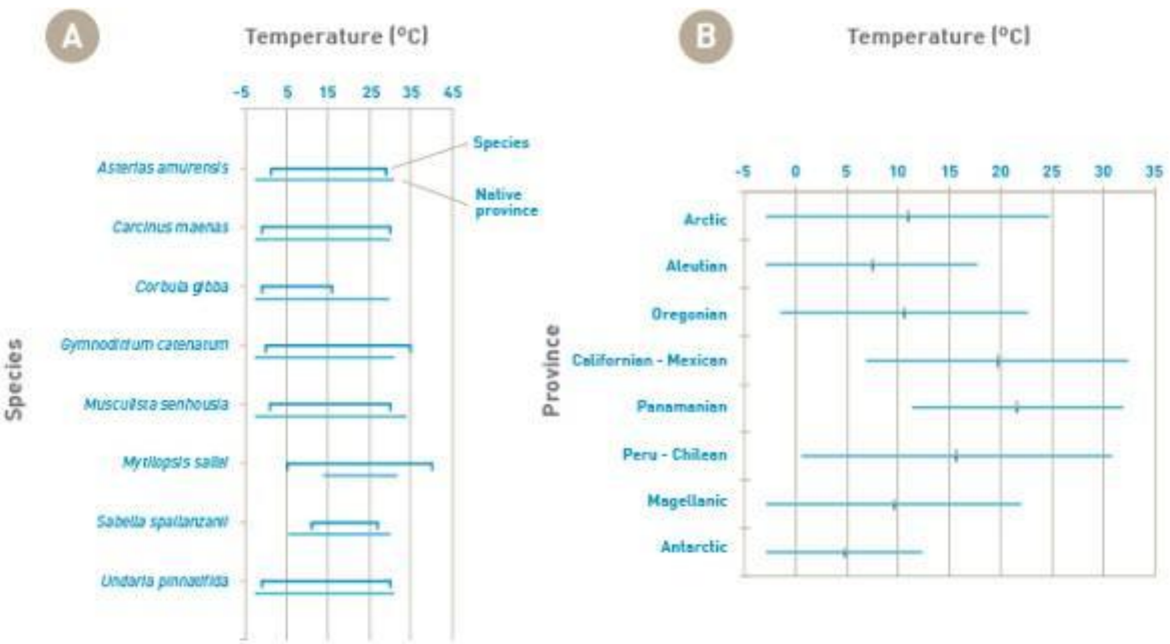


Non-indigenous marine species have been shown to fully realise their fundamental niche (sensu Hutchinson 1957), suggesting that their physiological tolerances are conservatively represented by the wide ranging environmental conditions (e.g. salinities and water temperatures) in their native distribution. In a previous evaluation (Hewitt & Campbell, unpubl. manuscript), the known temperature tolerances of several introduced marine pests in Australian waters were compared with the sea surface temperature maxima and minima (over a 10-year period) for their native provinces (see Figure 20a). The environmental range of temperatures in a species' native provinces conservatively describes the temperature tolerances of the species, suggesting that the environmental ranges of provinces can be used as conservative surrogates of species' tolerance levels.

As a consequence, the 'overlap' of environmental characteristics of different provinces may indicate the likelihood of species' survival in various regions. Significant provincial overlap occurs from the Arctic to the Antarctic along the eastern Pacific basin (see Figure 20b), suggesting that many species could survive in a wide range of provinces across the eastern basin, and that their restricted distributions may be constrained more by other factors (e.g. transport opportunity, receiving community resistance including predation and competition) than significant physiological 'resistance'. The northern and southern distribution of the large brown kelp, Macrocystis integrifolia is a case in point (Graham et al. 2007).

For the purposes of this report, the evaluation is to determine whether a species poses a risk for Australia as a nation. Australia covers a latitudinal range from 12° S to 43.5° S and has four biogeograhic provincial boundaries, with waters ranging from tropical to cool temperate (see Figure 8). Australia therefore has overlapping environmental conditions with much of the globe, suggesting that arriving species could probably survive in **at least one location of Australia**. A finer spatial scale would be required to determine a reduction in establishment due to environmental constraints alone.

Figure 20: Comparison of species' physiological tolerances versus native province sea surface temperature range **(A)**; and comparison of sea surface temperature for the eastern Pacific provinces **(B)** (from Hewitt & Campbell, unpubl. manuscript).



Species requirements are not limited to physiological tolerances and can include habitat requirements, such as substratum type, exposure gradients and nutrient availability. For all species considered in this analysis, the occupation of hard substrate–either directly as biofouling or in association with biofouling–is a key habitat requirement. Many of these species occupy both natural and man-made hard substrates in other regions of the world, specifically the port and marina structures including rocky breakwalls and protection groynes (e.g. Glasby et al. 2007; Dafforn et al. 2008; see also references in Campbell et al. 2007). These structures coincide with points of entry into Australia and are likely to represent the first substrate a new species will encounter once inoculated. As a consequence, no limitations to establishment based on habitat requirements are considered further here.

A second factor that contributes to a species' establishment success is the frequency and timing of its propagule (e.g. larvae or individuals) arrival into a new location (e.g. Ruiz et al. 2000; Fofonoff et al. 2003). This concept of 'propagule pressure' identifies that if several inoculation events of a single species occurred over time into a single location, then the opportunity for establishment is more likely to occur. Similarly, the hypothesis of propagule pressure suggests that a higher number of propagules arriving in a single location at the same time will increase establishment likelihood. The reasoning revolves around creating a population with increased ability to overcome 'founder effects', such as reduced reproductive success due to an inability to find a mate (e.g. Lockwood et al. 2007).

In this report, propagule pressure based on a higher number of propagules has been incorporated into the assessment of transport pressure. This had been done through the calculation of the number of opportunities for a species to arrive into Australia (i.e. vessel entries from regions where a species is found either as a native, cryptogenic or introduced population). Propagule pressure based on the arrival of a species through time has not been explicitly evaluated here, although the period of evaluation (2002 to 2007) and the consistency of vessel arrivals for most categories (excluding recreational vessels <25 m; see Figure 15) suggests that for Australia as a whole, species arrivals occur throughout the year.

Establishment can, however, be influenced by the residence time of a vessel in the receiving port. Residence time relates to the opportunity that a species has to reproduce, dislodge (for species capable of surviving and establishing once dislodged from a substrate) or depart (for mobile or sedentary species). The longer the duration of port stay, the greater likelihood a species has of inoculating the port. Information about how vessels' residence time in ports influences inoculation opportunity is also discussed in Section 2.3.1.

Additional hypothesised influences on establishment success include the influence of the recipient community on invasion success. This can occur by causing biotic resistance to new invasions through well established, species-rich communities leading to increased predation and/or competition by native species (e.g. Elton 1958; Hewitt & Huxel 2002; Dunstan & Johnson 2006). The empirical evidence suggests that biotic resistance does occur in some systems. In marine systems, small scale manipulations have also demonstrated negative relationships, with species-rich communities having low numbers of invasions (e.g. Stachowicz et al. 1999, 2002; Dunstan & Johnson 2006).

Alternatively, recipient communities can influence invasions through heightened susceptibility as a consequence of increased disturbance, including habitat replacement (e.g. Glasby et al. 2007; Dafforn et al. 2008) or invasional meltdown (e.g. Simberloff & von Holle 1999), whereby the effect of one invasion leads to the facilitation of subsequent invasions.

Given the location and community-specific factors leading to either biotic resistance or invasional meltdown it is impossible to incorporate these into this risk analysis as all have the potential to be operating in some location of Australia. Indeed, several of the previously cited studies are from Australian systems (e.g. Dunstan & Johnson 2006; Glasby et al. 2007; Dafforn et al. 2008) demonstrating that both biotic resistance and invasion susceptibility are occurring in the Australian marine environment.

2.3.3 Domestic spread

Domestic spread refers to progressive expansion and establishment of species in locations beyond the first site of establishment in the receiving country. This can be facilitated either by natural or human-mediated means. The likelihood of spread within Australia following an initial incursion has been evaluated based on species': life history characteristics, mechanisms and barriers to natural spread, opportunities to settle on transport vectors, frequency of transport opportunities, and the distal extent of transport opportunities.

Life history characteristics include a species' mobility (able to move by themselves), vagility (ease of movement, e.g. unattached) and/or reproduction strategy (asexual, sexual with planktonic gametes and/or larvae, larval period). Natural mechanisms and barriers to species spread in Australia include coastal currents and the north/south division of the continent into tropical and temperate climatic zones.

In contrast, human-mediated mechanisms of spread relate to the chances of transport that mirror the discussion of international transport patterns above. These include the potential to settle on a vessel, the frequency of vessel movements between domestic regions and the opportunity to depart a vessel in the receiving port. The opportunity to settle and depart a vessel relate to the time spent in ports by the various transport vectors including international vessels on voyages with domestic components, recreational vessels such as cruising yachts and fishing fleets.

2.3.3.1 Natural spread

The natural spread of organisms relies on a combination of species' life history traits and local environmental characteristics, including coastal current strength and direction, and the presence of accumulation zones for larval retention and entrainment (e.g. Grosholz & Ruiz 1995; Inglis et al. 2006; Bax & Dunstan 2007; DeRivera et al. 2007). These details will necessarily vary according to the species concerned and local port environmental characteristics (Inglis et al. 2006). For example, biofouling species typically have either a planktonic larval phase or alternative capacity for long distance spread. It can be expected that patterns of natural spread are in accordance with prevailing currents (see Figure 21), with those species with longer larval periods having greater capacity for spread via this mechanism.

The main pattern of natural spread via ocean currents can be expected: down the east coast from the Solanderian to the Peronian and Flindersian province; and down the west coast from the Damperian to the Flindersian province. Minimal natural spread can be expected against these main patterns. The connections between the Solanderian and Dampierian provinces are minimal and restricted to the throughflow in the Torres Strait region (see Figure 8 for explanation of provinces). While spread is likely to follow these patterns, local circulation patterns can be very complex and there is also potential for species to spread against the prevailing currents (Byers & Pringle 2006).

Figure 21: Major currents and circulation patterns around Australia. The continent is bounded by the Pacific Ocean to the east, the Indian Ocean to the west and the Southern Ocean to the south–from Hobday et al. (2007). Dashed lines represent variable currents.

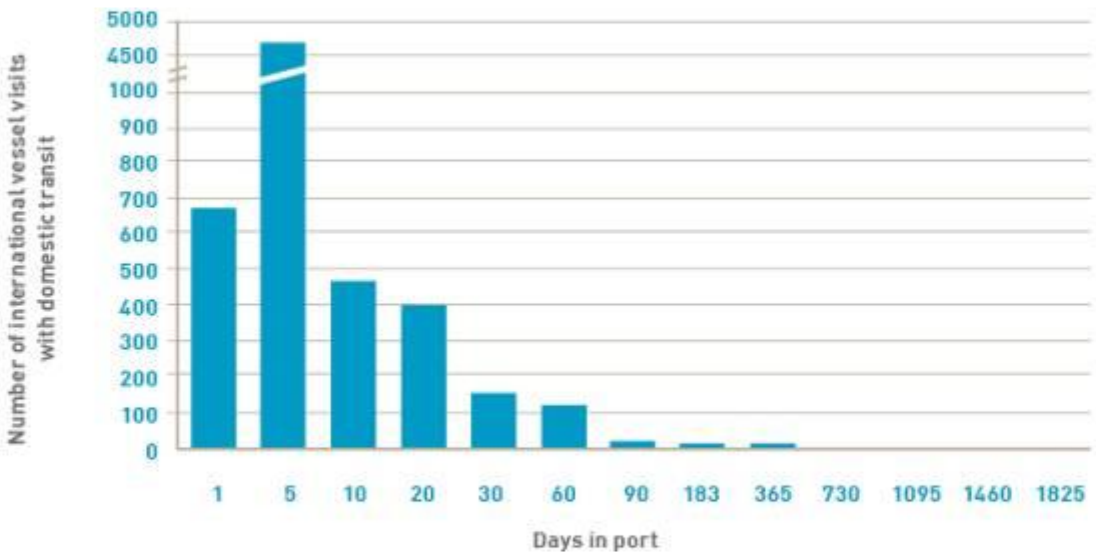
2.3.3.2 Human-mediated spread: Spread via international traffic trading domestically

Calculating the likelihood of an established species attaching to a new vessel in an Australian port is the same as that for an international port. Therefore, the previous risk assessments for inoculation (entry) and establishment of species can provide insights to domestic spread.

The likelihood of spread can initially be assessed as high based on: a species already having demonstrated an invasion history and an association with an active transport vector (biofouling); and a species having been assessed as highly likely to be able to become established in at least one Australian province. Given that more than 41% (±4.8%) of international vessels entering Australia will transit from the primary port of entry to additional Australian ports (see Figure 22), the possibility of species only inoculating the first port of arrival and not subsequent ports is low. This represents an annual average of 5595 (±796) international vessels which will act to spread species that are already associated with international vessels.

Time spent in port is likely to influence the opportunity for species to settle on a vessel as well as for species to depart an already infected vessel. The majority of international vessels entering Australia (average of 82.4% across years) will spend five or fewer days in the second port, however, an average of 121 (±23) vessels per year will spend greater than 30 days in the second Australian port (see Figure 22).

Figure 22: Duration of stay in second port of call by international vessels entering Australia between 2002 and 2007. Vessel visits represent the mean across years (Lloyds MIU dataset).



As identified above, more than 41% (±4.8%) of international vessel visits continue on to a second Australian port. The frequency of transport between the four Australian provinces provides an indication of the extent of probable spread. The majority of these vessels will visit a second port in a different province (see Table 9):

- 73.7% (±4.9%) of vessels entering a port in the Peronian province continued to another province
- 61.4% (±4.1%) of vessels entering a port in the Flindersian province continued to another province
- 58.8% (±6.3%) of vessels entering a port in the Solanderian province continued to another province
- 45.6% (±12.8%) of vessels entering a port in the Dampierian province continued to another province.

2.3.3.3 Human-mediated spread: Spread via domestic traffic

Domestic transfer of species is also likely to occur via domestic vessels, including commercial, petroleum, fishing, naval, non-trading vessels and recreational vessels, based on the reasoning used to assess likelihood of inoculation. Species arriving on an international vessel may therefore be transported to additional ports as part of this domestic reticulate web.

Detailed information about domestic vessels' movement patterns in Australian waters is limited. However, available data from Australia, combined with overseas work, provides compelling evidence that domestic traffic has the potential to be a significant vector for further spread of pest species (e.g. Floerl 2002; Kinloch et al. 2003; Floerl et al. 2009; Forrest et al. 2009; Acosta & Forrest 2009).

A review of the risk of spread for marine pests around Australia posed by domestic vessels from 23 sectors (e.g. cruise ships, customs launches, commercial fishing vessels) provides insight into the importance of these vectors (Kinloch et al. 2003). This review was not a quantitative analysis of specific movement patterns, but involved ranking domestic vessels on the basis of their characteristics and the nature and intensity of their activity in each sector. It was concluded from this analysis that commercial fishing vessels, dredges and offshore (petroleum) support vessels were likely to be the highest risk vectors for domestic spread of species (Kinloch et al. 2003). The high ranking of commercial fishing vessels in this study was on the basis of them: having a high likelihood of entraining marine pests due to them spending prolonged periods in commercial ports; being wide-ranging, regular and frequent users of the marine environment; and being highly mobile, often operating in different fishing grounds and from different ports. As is the case for most non-trading vessels, specific movement patterns of commercial fishing vessels are difficult to quantify and map because no records are kept of vessel movements or port visits, except in the case of a small proportion of the Australian Government-managed fleet that use vessel monitoring systems (Kinloch et al. 2003).

Particular vessel types, such as dredges, are believed to pose a high risk due to their unique behaviours relative to other vessel types–they move slowly and/or have long periods of port residency (>30 days). Many of these vessel types have been associated with a number of non-indigenous marine species detections (e.g. Carlton & Hodder 1995; Carlton 2001; Stafford et al. 2007; Davidson et al. 2009). Furthermore, slow-moving barges, dredges, research vessels and tugs that have been shown to transport intact communities (e.g. Coutts 2002) have also been implicated in transfers into and within Australia (e.g. Clapin & Evans 1995; Sabella transfers in Western Australia by a dredge that moved between Cockburn Sound, Bunbury, Albany and Esperance).

Another key vector for domestic spread is recreational vessels (e.g. Floerl & Inglis 2003; Ashton et al. 2006; Minchin et al. 2006; Acosta & Forrest 2009; Floerl et al. 2009). Surveys conducted along the Queensland coastline clearly highlight the importance of this vector (Floerl 2002). This study used multiple lines of evidence to demonstrate the potential role of this vector for spread of marine pests and involved biofouling sampling of yachts and marinas, along with questionnaire surveys to determine vessel movements. The work showed that these vessels can harbour a range of biofouling taxa, typically resembling the biofouling taxa in their home port. Furthermore, the work also showed that vessel movements have the potential to transfer pest organisms along the coastline. For 2192 trips recorded over the two-year survey period, most trips (46.5%) were relatively short (<20 km). However, 35.2% of trips covered 20 km to 100 km, 13.6% of trips covered 100 km to 300 km, 3.9% had travelled interstate, and 0.8% had travelled to overseas destinations. Importantly, the work showed that there was considerable exchange of vessels between widely separated marinas (encompassing more than 1000 km of coastline). Overall, the results of this study provide strong evidence that recreational vessel movements are able to facilitate the spread of marine pests along the Queensland coastline at a rate that greatly exceeds natural dispersal (Floerl 2002).

Table 9: Trading relationships between and within the primary Australian provinces based on percentage of international vessels entering Australia (first port) and continuing to a second port. The average percentage for: **(A)** 2002 to 2007; **(B)** 2002; **(C)** 2003; **(D)** 2004; **(E)** 2005; **(F)** 2006; **(G)** 2007.

A — First Port (columns) / Second Port (rows)

ALL	SOLANDERIAN	PERONIAN	FLINDERSIAN	DAMPIERIAN
Solanderian	41.20%	17.80%	4.80%	7.30%
Peronian	47.30%	26.30%	46.30%	8.60%
Flindersian	7.40%	53.40%	38.60%	29.70%
Damperian	4.10%	2.60%	10.40%	54.40%

B — First Port (columns) / Second Port (rows)

2002	SOLANDERIAN	PERONIAN	FLINDERSIAN	DAMPIERIAN
Solanderian	36.60%	17.70%	6.20%	8.10%
Peronian	50.30%	21.20%	41.10%	14.60%
Flindersian	8.10%	57.70%	38.50%	36.30%
Damperian	4.90%	3.40%	14.10%	41.10%

C — First Port (columns) / Second Port (rows)

2003	SOLANDERIAN	PERONIAN	FLINDERSIAN	DAMPIERIAN
Solanderian	36.90%	19.70%	5.70%	7.80%
Peronian	50.00%	21.30%	44.60%	10.60%
Flindersian	8.80%	56.10%	36.80%	39.70%
Damperian	4.30%	2.90%	12.80%	42.00%

D — First Port (columns) / Second Port (rows)

2004	SOLANDERIAN	PERONIAN	FLINDERSIAN	DAMPIERIAN
Solanderian	38.30%	17.70%	5.20%	6.10%
Peronian	49.30%	29.70%	45.40%	7.80%
Flindersian	8.70%	50.10%	39.40%	35.90%
Damperian	3.70%	2.50%	10.10%	50.20%

Table 9: (continued)

E

First Port

2005 (Second Port)	SOLANDERIAN	PERONIAN	FLINDERSIAN	DAMPIERIAN
Solanderian	38.20%	19.40%	4.80%	7.20%
Peronian	50.70%	23.00%	52.00%	8.40%
Flindersian	6.80%	55.00%	34.40%	28.10%
Damperian	4.30%	2.50%	8.70%	56.30%

F

First Port

2006 (Second Port)	SOLANDERIAN	PERONIAN	FLINDERSIAN	DAMPIERIAN
Solanderian	53.00%	16.70%	3.20%	6.90%
Peronian	39.00%	31.60%	43.20%	3.70%
Flindersian	5.20%	50.00%	46.10%	14.90%
Damperian	2.90%	1.70%	7.50%	74.40%

G

First Port

2007 (Second Port)	SOLANDERIAN	PERONIAN	FLINDERSIAN	DAMPIERIAN
Solanderian	44.10%	15.30%	3.80%	7.90%
Peronian	44.70%	30.70%	51.20%	6.80%
Flindersian	6.60%	51.50%	36.20%	23.00%
Damperian	4.60%	2.40%	8.90%	62.30%

Similar quantitative studies examining species spread via this vector are lacking for other regions of Australia, but there is a strong likelihood that the patterns observed in Queensland would also apply elsewhere. This is supported by anecdotal information, such as the influx of international and interstate cruising vessels arriving in Tasmania during the summer cruising season (D Shields, pers. obs.). International cruising yachts arriving in Australia typically cross the Pacific during the trade-wind season to arrive in Bundaberg or Cairns in October before heading south to escape the cyclone season. Many of these cruising yachts sail as far south as Sydney and some continue to Tasmania. Iconic events such as the annual Sydney–Mooloolaba–Cairns, Sydney–Hobart and Melbourne–Hobart yacht races, the biennial Tasmanian Wooden Boat Festival and the tall ships' circumnavigations involve both participants and followers conducting long coastal voyages between widely separated ports and anchorages. Each autumn a fleet of cruising yachts heads from temperate ports to warmer tropical waters and returns the following spring (D Shields, pers. obs.).

Previous work has ranked the commercial fishing sector as posing the highest risk of all marine transport sectors of domestically translocating marine pests (Kinloch et al. 2003). Approximately 12 000 fishing vessels ranging in size from 5 m dinghies to 80 m deep sea trawlers work from ports all around Australia (Kinloch et al. 2003). The largest Australian-managed commercial fishery is the Eastern Tuna and Billfish Fishery which employs 40% of Australian-managed commercial fishing vessels (Kinloch et al. 2003) and extends from Cape York, Queensland, around Tasmania to the South Australian/Victorian border. Fishing occurs in both the Australian fishing zone and adjacent high seas (AFMA 2009). Major ports used by the fleet include Cairns, Mooloolaba, Coffs Harbour, various south coast New South Wales ports and Hobart. Another important fishery, targeting Southern Bluefin Tuna, extends completely around Australia. The Northern Prawn Fishery is located off Australia's northern coast and extends from the low water mark to the outer edge of the Australian fishing zone in the area between Cape York in Queensland and Cape Londonderry in Western Australia (AFMA 2009). These three large fishing fleets alone have the capacity to translocate biofouling species between ports around Australia.

A survey in 2007 of a variety of commercial fishing vessels in ports around Australia found biofouling on all but one of the 14 vessels inspected. In that survey, 190 biofouling species were identified, including 30 non-indigenous marine species (Aquenal, unpubl. report). This survey inspected vessels after they had been hauled out of the water, so it may have missed mobile species associated with biofouling. The home ports of many fishing vessels are man-made harbours within commercial trading ports. Fishing fleets routinely spend extended periods laid up in harbour waiting on weather conditions or the opening of fishing seasons. Many fishing vessels follow the fish and unload their catch and reprovision far from their home ports. Fishing harbours are often crowded with vessels from different fleets and widely distributed home ports–providing ample opportunity for biofouling organisms carried on fishing vessels to inoculate the harbours and other fishing vessels in the vicinity.

Ultimately, once a species has become 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. As successive hubs colonise, the number of populations from which natural spread can occur increases via natural dispersal (Floerl 2002). This pattern of spread, termed the 'hub and spoke' dispersal (sensu Cartlon 1996) is typical of marine pest species (Carlton 1996; Cranfield et al. 1998). Recent modelling analysis indicates that spread of invasive organisms not only occurs from hubs, but also from seemingly unimportant transport nodes (Floerl et al. 2009). Nonetheless, transport hubs were consistently more likely to become infested by an invader species and to accelerate spread to secondary locations faster when compared with low traffic nodes (Floerl et al. 2009).

2.3.3.4 Domestic spread: Evidence from previous pest incursions in Australia

Patterns of spread following incursions of marine pest species in Australia provide additional evidence that domestic spread is likely following initial establishment. A number of examples are cited below.

- *Asterias amurensis*: The Northern Pacific seastar was first detected in the Derwent Estuary, Tasmania in 1986 (Buttermore et al. 1994) and has since spread throughout sheltered south-east Tasmanian bays. It has also spread to the north-east coast of Tasmania (A Morton, pers. comm.) and across Bass Strait to Port Phillip Bay (Cohen et al. 2000). While long-distance dispersal is possible (Dunstan & Bax 2007) given that this species has a long larval period (120 days–Bruce et al. 1995), *A. amurensis* was almost certainly transported across Bass Strait by vessel traffic between Tasmania and the mainland (Kinloch et al. 2003).

- *Undaria pinnatifida*: Following invasion of the east coast of Tasmania in 1988 (Sanderson 1990), the Japanese seaweed spread via natural dispersal at a rate of five to 10 km per year (Sanderson 1997). Subsequently, range expansions up to 50 km were observed. While not proven, these larger dispersal events are considered to be attributable to spread via domestic vessels (Sanderson 1997). Similarly, the colonisation of Port Phillip Bay in 1996 (Campbell & Burridge 1998) was likely to be due to domestic transfer.

- *Sabella spallanzanii*: The spread of the European fan worm down the Western Australian coastline is believed to be due to movement of dredges in the region (Clapin & Evans 1995). The species is known to occur in South Australia, Victoria and Tasmania and is likely to have spread through natural dispersal and association with fishing industry operations and as biofouling (NIMPIS 2002a).

- *Carcinus maenas*: The European green shore crab was originally introduced to mainland Australia (Victoria) around 1900 (Fulton & Grant 1900). In the 1970s it was identified in New South Wales (Hutchings et al 1989), South Australia (Zeidler 1978) and in 1993 in Tasmania (Gardner et al. 1994). A single record in the Swan River, Western Australia was found in 1965, but has not been detected since. Thresher et al. (2003) described the spread of *C. maenas* in Australia from its initial invasion in Victoria into New South Wales and Tasmania.

2.3.3.5 Summary of domestic spread

The subsequent spread of non-indigenous marine species once introduced into a new region will occur through the natural spread of organisms and through human-mediated movements. Natural spread is typically associated with currents, including drift, wind-driven movement and mobility for some species (e.g. salmonids). As discussed previously, the large-scale pattern of spread via ocean currents in Australia would be down the east coast (from the Solanderian to the Peronian and to the Flindersian province) and down the west coast (from the Damperian to the Flindersian province); (see Figure 21). At smaller scales, prevailing currents coupled with wind-driven circulation would determine spread.

In contrast to natural spread, human-mediated spread of non-indigenous marine species is similar to the calculations for international spread. For species attached to entering international vessels, more than 41% of international vessels entering Australia continue to a second (or more) domestic port. Many of these subsequent visits are for periods greater than 30 days (121±23 vessels per year; see Figure 22). In addition to international traffic transiting between domestic ports, domestic traffic will provide opportunities for secondary spread of non-indigenous marine species. The vessel groupings of recreational, fishing, domestic trading, domestic non-trading, domestic petroleum (specifically the service vessels) and naval vessels all provide opportunities for the translocation of species from primary points of entry to subsequent locations. Commercial fishing vessels were identified by Kinloch et al (2003) as the highest domestic risk based on: having a high likelihood of entraining marine pests due to them spending prolonged periods in commercial ports; being wide-ranging, regular and frequent users of the marine environment; and being highly mobile, often operating in different fishing grounds and from different ports. Similarly, dredges and slow moving barges may pose a high level of risk due to similar behaviour patterns.

Several previous pest incursions into Australia have experienced subsequent spread. The high profile invasions of *Asterias amurensis, Undaria pinnatifida, Sabella spallanzanii* and *Carcinus maenas* have all exhibited secondary spread following initial invasions. These secondary spread events have been through combinations of natural and human-mediated vectors, with large-scale movements being facilitated by human activity.

The likelihood of human-mediated domestic spread of these species is high–in accordance with the species' likelihood of initial inoculation and establishment. Numerous suitable vectors exist, including foreign vessels transiting between domestic ports, domestic trading vessels, domestic non-trading vessels such as fishing fleets, petroleum industry vessels and dredges, and recreational vessels. The only natural barrier to spread identified in this analysis applies to the small number of freshwater pest species. For these species, the presence of elevated salinities in coastal waters provides a barrier to further spread.

2.4 Calculating risk

Estimated risk has been assessed for each core value (i.e. environmental, economic, social/cultural, and human health) against a standard risk matrix using the inoculation likelihood multiplied by the consequence rank for each core value. Risk is then described in qualitative terms, ranging from negligible to extreme (see Table 10).

Table 10: Risk calculation matrix (modified from Campbell 2008).

N = negligible
VL = very low
L = low
M = moderate
H = high
E = extreme

Likelihood \ Consequence	NEGLIGIBLE	VERY LOW	LOW	MODERATE	HIGH	EXTREME
NEGLIGIBLE	N	VL	VL	L	L	L
EXTREMELY LOW	VL	L	L	L	M	M
VERY LOW	VL	L	L	M	M	M
LOW	L	L	M	M	H	H
MODERATE	L	M	M	H	H	E
HIGH	L	M	M	H	E	E

The outcomes of the risk assessments indicate that 56 of the remaining 162 species are identified as having extreme, high or moderate risk in at least one core value category when evaluated for all vessel categories between 2002 and 2007 and for all voyage durations (see Table 11). Eighty-four percent of these 56 species pose a moderate, high or extreme risk to environmental values. Sixty-nine percent of the species pose a moderate, high or extreme risk to economic values. Seventeen percent pose a moderate, high or extreme risk to both social and cultural, and human health core values. A large proportion (43.1%) of species represent a moderate, high or extreme risk to only one core value with 31% of species representing a risk to two core values; 20.7% (*Balanus eburneus*, *Balanus improvisus*, *Charybdis japonica*, *Didemnum vexillum, Dreissena bugensis, Dreissena polymorpha, Cliona thoosina, Crassostrea virginica, Mytilopsis sallei, Limnoperna fortunei, Sargassum muticum and Ulva pertusa*) are a risk to three core values; and 5.2% (*Eriocheir sinensis, Perna perna and Perna viridis*) are a risk to four core values. Several of these species, including *E. sinensis, P. viridis, P. perna, and M. sallei*, have previously been identified as species of concern by Australia.

Several biofouling-associated species not present in Australia that are currently listed by State jurisdictions as species of biosecurity concern are not recorded on this list of biofouling risk species (e.g. the *bivalves Ensis directus, Perna canaliculus* and the crab *Hemigrapsus penicillatus*). This outcome is due to a number of reasons–*P. canaliculus* is not considered to have successfully established as an invader anywhere in the world, despite the previous detection of a small population in South Australia (*V. neverauskas*, pers. comm.). In contrast, both *E. directus* and *H. penicillatus* have a moderate biofouling association, limited recognised global distributions and a poor demonstration of impacts, resulting in risk rankings less than moderate for any individual core value (see Appendix B).

For voyage durations of increasing length, more species are deemed to have a significant and quantifiable risk according to this assessment methodology; Figure 23 illustrates the change in risk categorisation for the four core values. Increasing voyage duration slightly increases the risk categorisation for individual species due to the vessel's passage through a higher number of bioregions (see Figures 11, 12, 13). However, this assessment found no consequent increase in the identified risk species (see Figure 23). This may be due to the levelling off of the mean number of bioregions entered after 183-day (six months) voyages (see Figure 11).

2.4.1 Assessment and ranking of overall risk

In order to assess and rank overall risk for the 56 identified species, a ranking scheme was devised. This involved assigning a rating for each risk level (1=moderate, 3=high, 5=extreme) and then summing the ratings across the four core values to provide an overall risk value. The ratings used to determine overall risk rankings were as follows:

- moderate: sum of risk ratings = < 3
- high: sum of risk ratings = 3-4
- extreme: sum of risk ratings = ≥ 5
- As can be seen in Table 11, when the risk ratings were summed across the four core values:
- 21 species were in the moderate risk category
- 14 species were in the high risk category
- 21 species were identified in the extreme risk category.

Six species that have overall risk values ≥ 10 (double the extreme value) are *B. improvisus*, *C. japonica*, *E. sinensis*, *S. muticum*, *P. perna* and *P. viridis*. These species represent a suite of global invaders, with documented impacts across a range of values.

Table 11: Species with risk rankings of moderate **(M)**, high **(H)** or extreme **(E)** in at least one core value and in at least one voyage duration. Moderate, high and extreme ranks were given scores of 1, 3 and 5 respectively to determine overall risk ratings and overall risk ranks.

PHYLUM	SPECIES	RISK RANK				OVERALL RATING	OVERALL RANK
		ENVIRONMENT	ECONOMY	SOCIAL/CULTURAL	HUMAN HEALTH		
Annelida	*Hydroides dianthus*		M			1	M
Annelida	*Polydora nuchalis*		H			3	H
Arthropoda	*Acartia tonsa*	M				1	M
Arthropoda	*Ampelisca abdita*	M				1	M
Arthropoda	*Balanus eburneus*	E	M		H	9	E
Arthropoda	*Balanus glandula*	H				3	H
Arthropoda	*Balanus improvisus*	H	E		H	11	E
Arthropoda	*Briarosaccus callosus*		H			3	H
Arthropoda	*Callinectes sapidus*		H			3	H
Arthropoda	*Carcinoscorpius rotundicauda*				H	3	H
Arthropoda	*Charybdis japonica*	H	E		E	13	E
Arthropoda	*Chthamalus proteus*	H				3	H
Arthropoda	*Crangonyx floridanus*	M				1	M
Arthropoda	*Dikerogammarus villosus*	M				1	M
Arthropoda	*Eriocheir sinensis*	H	H	H	H	12	E
Arthropoda	*Gammarus tigrinus*	M				1	M
Arthropoda	*Gmelinoides fasciatus*	H				3	H
Arthropoda	*Hemigrapsus sanguineus*	H	H			6	E
Arthropoda	*Loxothylacus panopaei*	M	M			2	M
Arthropoda	*Pachygrapsus fakaravensis*	M				1	M
Arthropoda	*Rhithropanopeus harrisi*	H	H			6	E
Arthropoda	*Solidobalanus fallax*	H	M			4	H
Arthropoda	*Sphaeroma annandalei*	H	M			4	H
Arthropoda	*Sylon hippolytes*		H			3	H
Bacillariophyta	*Corethron criophilum*		M			1	M
Chlorophycota	*Avrainvillea amadelpha*	M	M			2	M
Chlorophycota	*Codium fragile atlanticum*	M				1	M

Table 11: (continued): Species with risk rankings of moderate **(M)**, high **(H)** or extreme **(E)** in at least one core value and in at least one voyage duration. Moderate, high and extreme ranks were given scores of 1, 3 and 5 respectively to determine overall risk ratings and overall risk ranks.

PHYLUM	SPECIES	RISK RANK				OVERALL RATING	OVERALL RANK
		ENVIRONMENT	ECONOMY	SOCIAL/CULTURAL	HUMAN HEALTH		
Chlorophycota	*Ulva pertusa*	H	H	H		9	E
Chordata	*Didemnum vexillum*	E	H	M		9	E
Heterokontophyta	*Pseudochattonella farcimen*	M	M			2	M
Heterokontophyta	*Chattonella antiqua*	M	M			2	M
Heterokontophyta	*Fucus evanescens*	M				1	M
Heterokontophyta	*Sargassum muticum*	E	E	H		13	E
Mollusca	*Anadara demiri*	M	M			2	M
Mollusca	*Anomia nobilis*	H				3	H
Mollusca	*Brachidontes variabilis*	H	H			6	E
Mollusca	*Corbicula fluminea*	M	H			4	H
Mollusca	*Corbula (Potamocorbula) amurensis*	M				1	M
Mollusca	*Crassostrea ariakensis*	M	M		H	5	E
Mollusca	*Crassostrea virginica*	H	H		H	9	E
Mollusca	*Crepidula fornicata*	H	H			6	E
Mollusca	*Dreissena bugensis*	M	H	M		5	E
Mollusca	*Dreissena polymorpha*	H	H	M		7	E
Mollusca	*Geukensia demissa*	M				1	M
Mollusca	*Limnoperna fortunei*	H	H		H	9	E
Mollusca	*Mya arenaria*				M	1	M
Mollusca	*Mytella charruana*	M	M			2	M
Mollusca	*Mytilopsis leucophaeta*	H	E			8	E
Mollusca	*Mytilopsis sallei*	H	E	M		9	E
Mollusca	*Perna perna*	H	M	H	E	12	E
Mollusca	*Perna viridis*	H	M	H	E	12	E
Mollusca	*Rapana venosa (thomasiana)*	H	M			4	H
Nematoda	*Anguillicola crassus*	M	M			2	M
Porifera	*Cliona thoosina*	H	H	M		7	E
Porifera	*Gelliodes fibrosa*	M				1	M
Haplosporidia	*Bonamia ostreae*		H			3	H

Figure 23: Risk categorisation for environmental **(A)**, economic **(B)**, social/cultural **(C)** and human health **(D)** values for voyage durations of 30, 60, 90, 183 and 365 days.

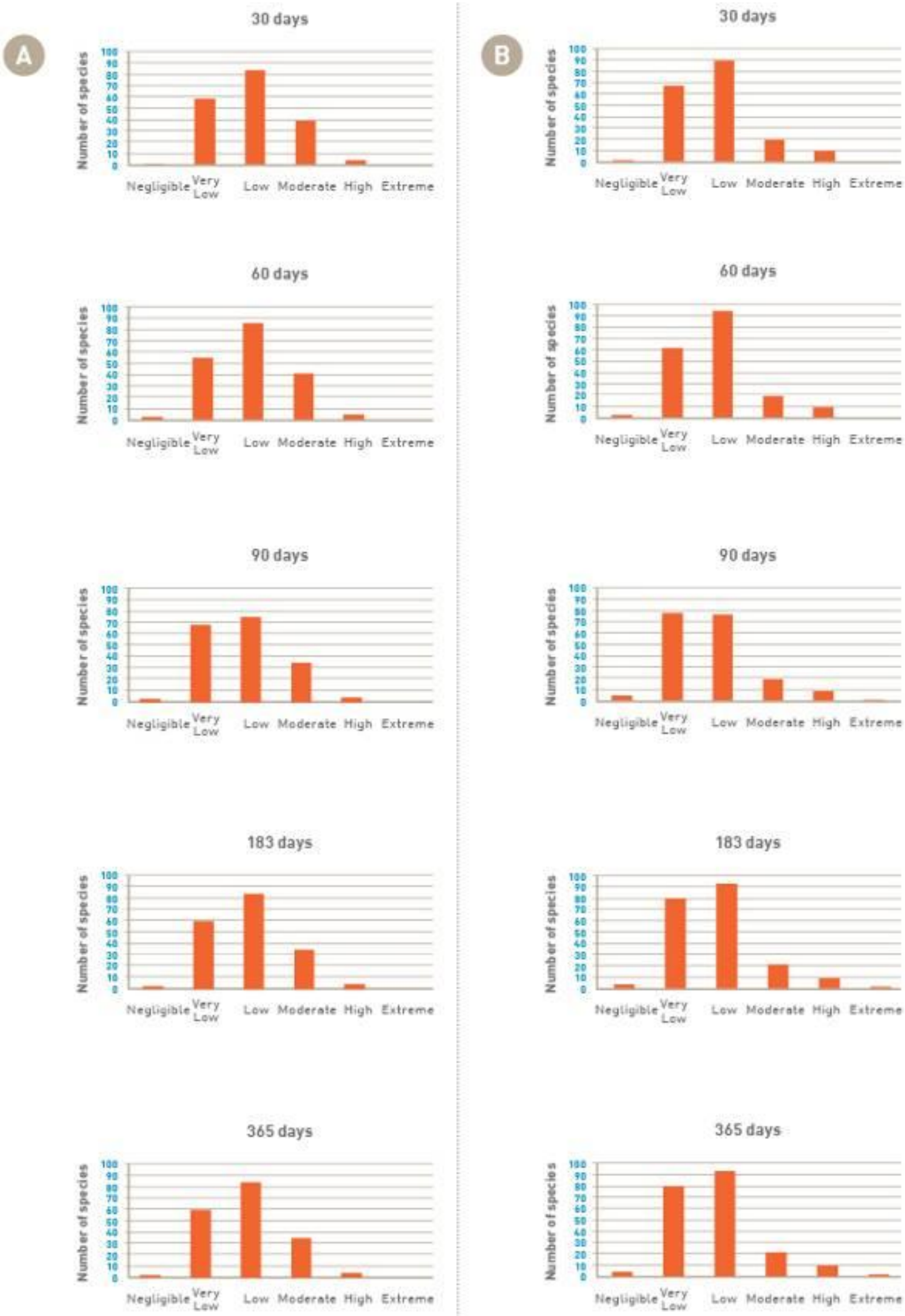
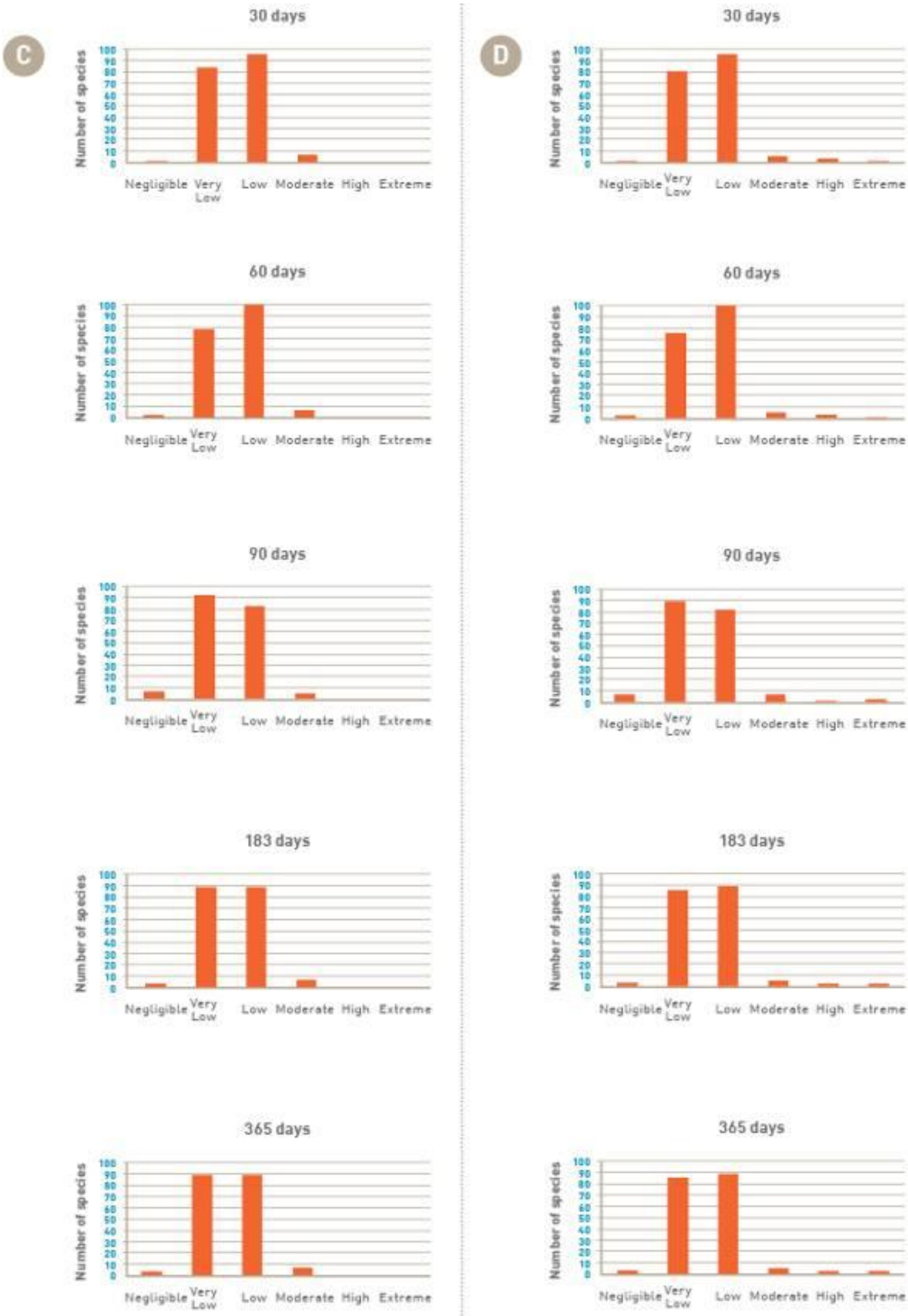


Figure 23: (continued)



2.5 Potential range of 56 pest species in Australia

An analysis was conducted to determine the potential Australian geographic range for each of 56 selected high risk species (i.e. those ranked in at least one core value as a moderate, high or extreme risk; see Table 11) based on environmental (temperature tolerance) overlap. The aim of this analysis was to determine whether water temperature may be a barrier to domestic spread for any of the 56 species.

The main environmental factor that could be reasonably investigated was water temperature. Sea surface temperature range derived from each species' current world-wide distribution (hereafter referred to as inferred temperature range) was firstly determined using IUCN bioregion data taken over a 10-year period (Hobday & Hewitt, unpubl. data). (Appendix F describes the bioregions in which each species is found.) Physiological temperature tolerance information was also compiled for those species where such detailed information was available. For each Australian province (see Figure 8), maximum and minimum values for sea surface temperature were then calculated (see Table 12) by combining Australia's bioregionalisation (Interim Marine Coastal Regionalisation of Australia [IMCRA] 4.0 and the Australian Meso-scale regionalisation) data across these provinces (Hobday & Hewitt, unpubl. data). Temperature tolerance of the various life stages of particular species could then be compared to the sea surface temperature range of each province within Australia (see Figure 24).

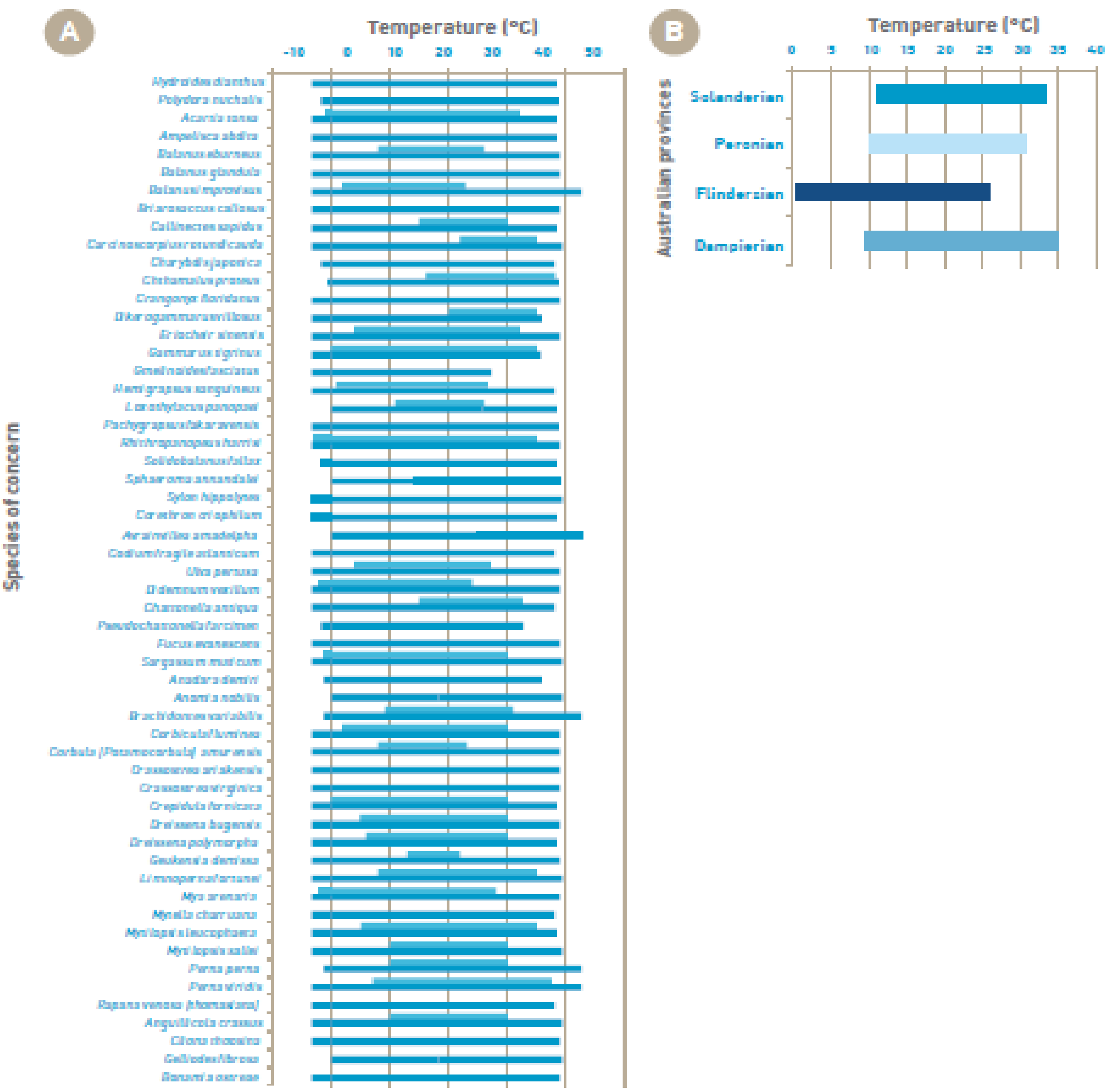
The overlap of the species' combined inferred and physiological temperature tolerance with Australian provinces' temperature ranges (see Figure 24a) predicts that all of the species are able to survive and reproduce within each of the four provinces. The approach used in this analysis–applying a large-scale distributional temperature range for each species using IUCN boundaries–provides a broader estimate than the known physiological temperature tolerance for most species (see Figure 24b) and a conservative estimate of environmental niche matching. Analysis at a finer spatial scale was not possible as detailed distributional information was largely unavailable for most species. The assumption that species found in an IUCN bioregion are able to exist within all areas of that bioregion is consistent with the approach used in the preceding risk analysis. Large-scale provinces in Australia were used to provide a comparable scale to the IUCN boundaries. Where there was information available for physiological temperature tolerance of particular species (see Figure 24a), this confirmed that these high risk species are likely to survive and be able to reproduce in a wide range of temperatures and in all of Australia's provinces.

An important factor which influences the establishment of a species at a new location is the temperature tolerance of its larvae, which is often more restricted than the adults' temperature tolerance (Turoboyski 1973; Romero & Moreira 1980). For example, the metamorphosis of larvae of *Rhithropanopeus harrisii* is limited to temperatures between 18 ˚C and 30 ˚C (Turoboyski 1973). This may restrict this species' survival in the Flindersian province to the higher latitudes and summer months. However, this is still in accordance with the prediction that this species can survive in the Flindersian province.

Salinity tolerance was also considered in relation to the potential range of pest species in Australia. Several of the selected species are freshwater species that are not tolerant of salinities greater than 25 ppt. These species include Crangonyx floridanus, Dikerogammarus villosus, Gammarus tigrinus, Gmelinoides fasciatus, Corbicula fluminea, Dreissena bugensis and Dreissena polymorpha. There are only a limited number of Australian ports where freshwater conditions are evident and these conditions are usually only seasonal. Therefore, survival of such freshwater species is unlikely in most Australian ports. In the unlikely event of such freshwater species establishing, there would be extremely limited capacity for domestic spread. Salinities typical of marine environments would prevent natural dispersal around the coast, so domestic spread would be restricted to translocation via anthropogenic vectors.

Factors such as nutrient requirements, habitat specificity and pH tolerance could not be included in the analysis of species' potential ranges due to the lack of information in the literature and the complexity of the broad provinces considered in this study. For parasitic barnacle species (Briarosaccus callosus, Loxothylacus panopaei and Sylon hippolytes), availability of host species may be a limiting factor, however, insufficient knowledge of potential hosts and their distributions is available to draw conclusions.

Figure 24: Comparison of species' physiological temperature tolerance versus their inferred temperature tolerance **(A)**; and sea surface temperature ranges for Australian provinces **(B)**[4].



Key: Comparison of species' physiological temperature tolerance (light blue lines) versus inferred temperature tolerance (dark blue lines) based on sea surface temperature range for current distributions in IUCN bioregions.

[4] Based on previous studies: Costlow & Bookhout 1957; Turoboyski 1973; Siddall 1978; Romero & Moreira 1980; Jegla & Costlow 1982; Paffenhofer & Stearns 1988; Hales & Fletcher 1989; Fiala & Oriol 1990; Balcom 1994; McDermott 1998; Ricciardi 1998; Segnini de Bravo et. al. 1998; Cohen & Weinstein 2001; National Introduced Marine Pests Information System (NIMPIS) 2002c; Rajagopal et al. 2002; Verlaque et al 2002; Verlaque et al. 2003; Hill 2004; Cohen 2005a,b,c; National Estuarine and Marine Exotic Species Information System (NEMESIS) 2005a; NEMESIS 2005b; Rajagopal et. al. 2005; Swedish Environmental Protection Agency (SEPA) 2005; Zabin 2005; Zaiko 2005; Galil 2006; Bullard et al. 2007; Cohen 2007; Mikhail 2007; Crosier & Molloy 2008; Minchin 2008. *Physiological tolerance information is unavailable for these species.

Table 12: Minimum and maximum sea surface temperatures (SST) for each Australian province derived from IMCRA bioregions.

PROVINCE NAME	MIN SST (°C)	MAX SST (°C)
Solanderian	10.95	33.15
Peronian	10.20	30.60
Flindersian	0.45	25.95
Damperian	9.60	34.65
Australian range	0.45	34.65

3.0 Discussion and conclusions

It is becoming widely recognised at public and policy levels that invasions of marine species present a clear and significant threat to the environmental, economic, social/cultural and human health values represented by the marine environment (e.g. Lubchenco et al. 1991; Pimentel et al. 2000a; Carlton 2001; Pimentel 2002; Hewitt et al. 2004, 2009a, b). This focus on the protection of the marine environment as well as the goods and service benefits it provides has been termed marine biosecurity (Hewitt et al. 2004, 2009a, b).

Marine biosecurity, specifically in its quarantine phase, relies on the management of risks through identification of hazards and assessment of the likelihood and consequences of those hazards (e.g. Hayes 1997; Hayes & Hewitt 1998, 2000; Hewitt & Hayes 2001; Hayes & Sliwa 2003; Campbell 2005, 2008, 2009; Campbell et al. 2007; Barry et al. 2008). Most marine biosecurity risk assessments focus on minimising the entry of unwanted or potentially harmful species (e.g. Hayes & Sliwa 2003; Campbell 2005, 2008) as evidenced by numerous 'black lists' of restricted organisms (e.g. Hayes & Sliwa 2003; Hewitt et al. 2004, 2009a, b). The identification of species for inclusion on 'black lists', or for the explicit development of regulations, requires the use of risk assessment.

Several vectors or mechanisms of transport have been implicated in the world-wide transfer of non-indigenous marine species (e.g. Carlton 1979, 1985, 2001; Ribera & Bouderesque 1995; Hewitt et al. 1999, 2004a, b). The global focus on ballast water-mediated marine invasions has dominated marine biosecurity efforts in the past several decades (e.g. Carlton 1985), despite recent work indicating that biofouling represents an equally significant threat (e.g. Hewitt et al. 1999, 2004; Thresher 2000; Gollasch 2002; Hewitt 2002, 2003; Fofonoff et al. 2003; Lewis et al. 2003, 2004; Ribera-Siguan 2003; Floerl & Inglis 2005; Minchin 2006, 2007; Schaffelke et al 2006; Schaffelke & Hewitt 2007; Hewitt & Campbell 2010).

This study clearly demonstrates that a number of exotic species associated with biofouling represent a risk to Australia. Out of the global suite of 1781 marine species with recognised invasion history, 793 were deemed to have some likely association with biofouling of vessels, fisheries or aquaculture gear by Hewitt and Campbell (2010).

Australia has a significant taxonomic knowledge base, with high endemicity (Poore 1995), and has invested in evaluations of its current state of marine introductions through literature and museum collection evaluations (Pollard & Hutchings 1990a, b; Hewitt et al. 1999, 2004) and a series of baseline port surveys (see Campbell et al. 2007; Hewitt & Campbell 2010). The present assessment interrogated this knowledge base and identified 657 of the 793 species as not being present in Australia.

Predicting impact of potential invasive marine species is problematic. Consequently, the predictions made in this report necessarily relied on work from overseas locations and for many species this was not readily available. Impact analyses have been recognised as a critical area of research largely lacking in the literature about invasive species (Carlton 1996; Vermeij 1996; Williamson 1996; Byers et al. 2002).

Consequence was evaluated across the four primary values: environmental, economic, social/cultural and human health. These core values were further divided using a suite of consequence matrices providing explicit exemplars of levels of impact (see Appendix A), including duration of impact (days/months/years), resilience (ability to recover) and scale/extent of impact (local/national/international).

Investigation of the literature found that only 162 species of the 657 not found in Australia had inferred or demonstrable impacts. As discussed previously, no investigations were found in the literature for 495 species to suggest that they were of insufficient interest to warrant investigation (and therefore were unlikely to have any inferred impact). An alternative reason for the lack of information in the literature may be that investigations had been undertaken which resulted in negative results, but details of these examinations remained unpublished (Jennions & Møller 2002; Dickersin & Min 2006). Additionally, a number of species for which investigations had been undertaken were found to have no impact (e.g. Forrest & Taylor 2002).

Furthermore, the evaluation relied on readily available literature, but was largely drawn from publications supplied in English and heavily weighted to North American, European and Australasian (Australia and New Zealand) regions. Regardless, only 162 species were found to have any discernable impact, resulting in a restricted set of species for analyses. Clearly some of the unstudied species could pose a threat to Australia across the four core values and would therefore be a priority for further investigation. For the purposes of this report, however, species with no inferred or demonstrated impact were excluded from further consideration.

For the 162 species, a further assessment of association with biofouling was coupled with an evaluation of transport pressure based on global distribution of the species (in both native and introduced bioregions). This enabled identification of the number of vessels arriving in Australia that **could have transported** the species to the continent's waters. This required a number of critical assumptions, including:

- a species' presence in a bioregion represents an established population **throughout** the bioregion
- all vessel categories are equally able to transport all species
- all trade routes from bioregions to Australia are equally 'stressful'.

These assumptions represent conservative approaches to the information available. The ability to discern a non-indigenous marine species' presence in overseas ports can be problematic (e.g. Hayes & Hewitt 1998, 2000; Hewitt & Hayes 2001, 2002; Barry et al. 2008). While there have been numerous efforts to provide current information on invasions into various global regions (see Campbell et al. 2007 for review), the information is typically out-of-date by the time it is in the peer-reviewed literature. Assuming that a report of a species in a bioregion represents an established population, this allows a risk manager to use the information in making an assessment. Similarly, assuming that a species is spread throughout the bioregion, when it may have only been reported from one location, addresses the significant lag time between incursion, detection and reporting. During this period, which can span more than a decade, the opportunity for the species to have spread through natural and human-mediated means creates the high likelihood that nearby regions and ports will have been infected.

Vessel category has been clearly recognised elsewhere as having characteristics that could influence inoculation pressure (e.g. Carlton 1985, 2001; Carlton & Hodder 1995; Coutts 1999; Wonham et al. 2000; Floerl 2002; Coutts & Dodgshun 2007; Piola et al. 2008). Vessel behaviours differ significantly both individually and across vessel categories. These behavioural differences include, but are not limited to, vessel speed, time spent in port, and maintenance history.

An evaluation of vessel speed based on the Lloyds MIU dataset indicated that no clear differentiation could be discerned by using the gross scale of vessel categories applied in this assessment. Clearly, some vessel types move at much slower speeds than others, and recent reports suggest that slower moving and sedentary vessels, including barges, dredges, drilling rigs and FPSOs, may harbour larger quantities and diversity of species than other vessels (e.g. Coutts 2002; Floerl 2002; Floerl & Inglis 2005; Davidson et al. 2009; Coutts et al. 2010). The relationship, however, between a vessel's maximum, or even mean, speed (representing sheer forces) and the successful transport of species to new regions remains unclear.

The presence of hydrodynamically protected or niche areas on a vessel's hull, such as sea-chests, rudders and propeller shafts (e.g. Clapin & Evans 1995; Gollasch 2002; Hayes 2002; Coutts et al. 2003; Coutts & Taylor 2004; Hayes et al. 2004b; Coutts & Dodgshun 2007) nevertheless, suggests that speed alone will not preclude a species' presence on a vessel, but may significantly reduce its abundance. Coutts (1999) evaluated commercial (merchant) vessels entering Bell Bay in Tasmania, Australia, and found that speed was a good correlate of species abundance and a moderate correlate for diversity. However, this study concentrated on the uniform areas of the hull surface and did not explore niche or protected areas of a vessel's hull.

Time spent in port by various vessel categories provides a clear indication of differences in opportunity for species to settle on the vessel (assumed to correlate with time in port). This factor has been used as a multiplier of vessel visits from a bioregion in this assessment to account for the increased likelihood that a species would be transported. The accumulation of biofouling in a small area of a vessel is unlikely to be a linear process; however, across the entire wettable surface area of a vessel, a species' accumulation may be assumed to be linear as described by the weighting function used here. Indeed the accumulation of species onto settlement panels often follows an exponential increase in diversity as the habitat increases in complexity (Sutherland & Karlson 1977). At some point, however, an asymptote (a levelling off) of the species' accumulation is expected to occur in the local patch, or more broadly once the community accumulates the entire species pool from a bioregion (Rosenzweig 2001). How rapidly the community is assembled varies widely across regions and time of year (Sutherland & Karlson 1977; Lewis 2002; Lewis et al. 2004; Dunstan & Johnson 2006).

As voyage duration increases, the number of bioregions visited was found to rise in a step-wise pattern with a mode after 90 days around three bioregions. Taking into account the expected operational cycle of vessels between dry-docking and antifouling paint applications, coupled with the restrictions placed on in-water cleaning in many jurisdictions, most vessels will be expected to have significant communities of species. Based on the assessment of voyage duration, multiple bioregions are visited by half of the vessels travelling for periods of less than one year. This in turn increases the opportunity for species from disparate regions to attach to the hull and also increases the total likelihood for individual species to be transported. Given that some vessels entering Australia in the study period (2002 to 2007) had participated in voyages of at least 183 days (six months), all 18 bioregions had been visited by at least one vessel entering Australia.

A number of vessel characteristics could not be evaluated and did not contribute to the final evaluation. As previously noted, vessel speed did not differentiate between vessel categories, but varied widely within several categories. Antifouling paint history, coupled with more generic hull husbandry information, could potentially provide significant information on the likely state of biofouling. However, this information could not be obtained at the scale required, and therefore could not be included in this assessment.

Of the 162 species for which inferred or demonstratable impacts across one or more of the core values (environmental, economic, social/cultural and human health) were recovered in the literature, and for which inoculation likelihood was assessed, a restricted suite of 56 species were deemed to have a risk equal to or greater than moderate. This outcome represents a similar level of risk as identified by previous evaluations for ballast water-vectored species (Hayes & Sliwa 2003; Hayes et al. 2004a).

Several of these species exhibit risk across multiple values. For example, the Asian green mussel (*P. viridis*), brown mussel (*P. perna*) and Chinese mitten crab (*E. sinensis*) are ranked as moderate to extreme risk across all four values. The use of multiple values, against which risk is assessed, provides a broader understanding of the threats to Australia's marine environment and its maritime economy. By presenting risk in this manner, managers can better represent the threats to those elements that stakeholders find most relevant.

The 56 species identified as representing an increased risk to Australia include species that impact aquaculture activities, coastal industries, wild fisheries and other living marine resources, protected and habitat-forming species, social/cultural values and human health (see Table 11 and Appendix F). Several have already been identified as 'next pests' by marine researchers (e.g. Hayes & Sliwa 2003; Hayes et al. 2004a). The 56 species listed in Table 11 are all likely to arrive (inoculate) and establish in at least two major provinces of Australia. Subsequent spread is likely as the same methods for international inoculation and establishment will be used to facilitate domestic spread.

In conclusion, a total of 56 species were found to pose a risk greater than moderate when assessed across all vessel entries to Australia. This assessment explicitly analysed these species for establishment and spread endpoints and found that all species had the likelihood to establish in some location of Australia and subsequently spread.

AFMA dataset An internal database maintained by the Australian Fisheries Management Authority (AFMA) of illegal foreign fishing vessels.

Antifouling paint Any coating (generally applied as a paint) specifically designed to prevent or deter the settlement and growth of biofouling organisms on a submerged surface (e.g. vessel hull), including biocidal coatings and fouling-release coatings.

AQIS pratique dataset Australian Quarantine and Inspection Service (AQIS) vessel monitoring system dataset; an internal electronic system maintained by AQIS.

Australian waters Includes State and Territory coastal waters, territorial seas, contiguous zones and Australia's exclusive economic zone which extends 200 nautical miles (370 km) out from Australia's coastline. This term also covers the joint petroleum development area–an area of the Timor Sea with overlapping territorial claims between Australia and Timor Leste.

Ballast water Any water (including associated sediments) taken on board a vessel for the express purpose of maintaining its trim and stability during a voyage.

Benthic species Flora and fauna found on, or associated with, the ocean floor.

Biofouling Marine organisms attached to: any submerged artificial structure, including wharves, jetties and any part of a vessel hull (including the rudders, propellers and other hull appendages); internal seawater systems (including sea-chests and pipe work); or equipment or equipment spaces attached to or onboard the vessel (including mooring devices, anchor wells, cable lockers, cargo spaces, bilges, etc).

Bioregion An area constituting a natural ecological community with characteristic flora, fauna and environmental conditions, and bounded by natural rather than artificial borders.

Biosecurity Managing the risks associated with pests and diseases which could potentially cause harm to human, animal or plant health, as well as the environment or economy, from entering, emerging, establishing or spreading in a given area.

Biotic resistance The hypothetical resistance to new species entering a community by the existing members. Elton (1957) suggested that well connected, species-rich communities would naturally resist new species entering by predation, parasitism, and direct and indirect competition.

Colonise Larvae or propagules that successfully settle and establish on a submerged substrate.

Commercial vessel 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; 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 adverse event or hazard.

Demonstrable impact An impact that has been scientifically demonstrated through observation and/or empirical evaluation.

Donor port The port from which a species is likely to be transported to a receiving port or region.

Dry and semi-dry ballast The largely historic 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 quarantine-based (prevention of entry) or impact-based (prevention of impact).

Epibenthic species Living on the surface of the benthic substrate on the bottom of the ocean or estuary.

Epifauna An animal growing on top of the substrate.

Established species A non-indigenous species that produces a self-sustaining population which reproduce and recruit individuals to replace loss from the population.

Establishment A non-indigenous species that is inoculated into the new (introduced) environment and recruits, settles or attaches and subsequently survives in the new environment. Establishment also includes survival and development of a self-sustaining population.

Event In risk assessment, an event (often referred to as a hazard) is an activity that may lead to an undesirable outcome.

Fecundity The number of offspring produced, usually by an individual.

Fishing vessel Legal commercial vessels engaged in the industry of capturing wild stocks, including: fishing (general); trawler (all types); whaler; fish carrier; and fish factory.

Freshwater species For the purposes of this report, freshwater species are defined as species restricted to water of less than 3 ppt salinity.

Hazard A situation or event that could lead to harm.

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.

Illegal foreign fishing vessel (IFFV) Foreign vessel apprehended for fishing illegally in Australia.

Indigenous or native Species that are naturally occurring in a region, having evolved or migrated into a region without human intervention.

Infauna An animal growing inside a substrate.

Infect Transfer of a species to a transport vector (vessel), such as the settlement of benthic organisms onto a vessel hull.

Inferred impact An impact that is identified by an expert as possible or probable, however, has not been empirically demonstrated.

Inoculate/inoculation Release of a non-indigenous marine species into the surrounding environment. Includes release of offspring, fragments and/or direct transfer of individuals, but does not infer successful establishment.

Inoculation likelihood The probability of a species arriving in a new location. For the purposes of this report it is a categorical ranking of the probability of arrival in Australia for individual species combining a species, biofouling association rank with the transport likelihood (the proportion of vessels arriving from regions where the species is known to be present).

Introduced, non-indigenous, exotic marine species Species that have been transported by human activities–intentionally or unintentionally–into a region in which they did not historically occur.

Introduction The human-mediated movement of an animal to an area outside its natural range.

Invasional meltdown The hypothetical situation where one invading species can facilitate subsequent invasions thereby creating a positive feedback loop.

Invasive species A species (or organisms) that cause, or is likely to cause, damage to the environment, economy (e.g. agricultural or aquaculture activities, wild fisheries stocks) or human health.

Last port of call The last official port visited by a vessel prior to entering another port jurisdiction.

Likelihood The probability or frequency of an adverse event or hazard occurring.

Lloyds MIU Lloyds Maritime Intelligence Unit.

Marine pest Any exotic marine species that poses a threat to the marine environment, economy (industry), societal values or human health if introduced, established or translocated.

Meroplankton Category of organisms that spend a part of their life cycle in the water column as plankton. For invertebrates and many fishes, the planktonic stage is usually the larval stage.

Naval vessels Naval vessels and auxiliary tankers.

Next port of call The next official port to be visited by a vessel after leaving a port jurisdiction.

Non-trading vessel Vessel category that includes: barge; cable ship; crane ship; cutter suction dredger; dredger; ferry; fire fighting tug; fire fighting tug supply; fishery protection; grab dredger; hopper barge; hopper dredger; icebreaker; landing craft; lighthouse/tender; meteorological research; oceanographic research; patrol ship; pollution control vessel; pontoon; pusher tug; research; research/supply ship; salvage tug; seismographic research; semi-submersible heavy lift vessel; suction dredger; tank barge; trailing suction hopper dredger; training; tug; tug/supply; and yachts >25 m or super-yachts.

Petroleum vessel Vessel category that includes: anchor handling fire fighting tug/supply; anchor handling tug/supply; diving support; drill platform; drill ship; floating gas production; floating production tanker; floating storage tanker; offshore safety; pipe layer; product tanker; supply; and support.

Plankton Collective name for all the forms of drifting or floating organic life found in the ocean or in fresh water.

Primary biofouling First stage or level of biofouling and includes the biochemical and bacterial conditioning of a submerged surface and the accumulation of microalgae (<1 mm) and filamentous algae (<5 mm).

Primary literature Peer reviewed journals and books, generally presenting original findings.

Propagules Reproductive offspring of aquatic invertebrates (larvae) and algae (propagules) and/or individuals.

Qualitative A subjective assessment that does not necessarily involve any measurements and often uses non-quantifiable information.

Qualitative risk assessment Risk assessment that relies on subjective assessments, including heuristic assessments of expert or stakeholder opinion.

Quantitative An objective assessment in which measurements will be, or have been, made (e.g. mean number of organisms per sampling unit).

Quantitative risk assessment Also known as probabilistic risk assessment, it involves assessors describing the elements of risk (i.e. likelihood and consequence) numerically. However, this is often replaced with qualitative descriptors representing categories or bands of numerical risk (this is often referred to as semi-quantitative risk assessment).

Recreational vessel Non-commercial vessel designed for non-commercial use, intended to be operated by, and carry, at least one person within the confines of a hull. For the purposes of this report, recreational vessels are restricted to vessels <25 m, and recreational vessels >25 m are reported as 'non-trading vessels', due to variations in regulatory controls across Australia. Windsurfers, surfboards, rafts and tubes are not considered recreational vessels.

Recruitment The post-settlement survival of an individual or species within a defined time period.

Reproductive phenology The timing and period (duration) of reproductive activity for an individual species.

Risk The product of likelihood (frequency) and magnitude (consequence) of an event or hazard.

Risk analysis Risk analysis is made up of three components: risk assessment, risk management and risk communication. The process seeks to identify the relevant risks associated with a proposed introduction and to assess each of those risks.

Risk assessment The method used to determine the likelihood (frequency) of a particular event (risk) occurring and its possible consequences (magnitude). In a marine biosecurity context, risk assessment consists of five steps: identifying endpoints, identifying hazards, determining likelihood, determining consequences and calculating risk.

Sea-chests 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.

Secondary biofouling Second stage of biofouling which can take the form of acorn and gooseneck barnacles, bryozoans, hydroids, serpulid worms, spirorbid worms, algal tufts, coralline algae, or amphipods.

Secondary literature Generally non-peer reviewed literature, including 'grey' literature such as websites, policy documents, databases, reports; also includes encyclopaedias and dictionaries.

Sedentary Species that are unattached or weakly attached to the substratum, but generally do not significantly move around (e.g. seastars, anemones, some clams).

Semi-quantitative risk assessment The replacement of continuous numerical values describing the elements of risk (likelihood and consequence) with qualitative descriptors representing categories or bands of numerical risk.

Sessile Species such as sponges, corals and barnacles that are firmly attached to the hard substratum.

Settlement In a marine ecology context, it is the process of a species transferring from the water column to the benthic substrate, usually associated with metamorphosis from larvae (juvenile phase) to adult. Settlement represents the act of settling, whereas recruitment is a term that infers survival after some period of time post-settlement.

Spread The movement and establishment of a species, either by natural or human-mediated means into new locations beyond their first site of establishment.

Tertiary biofouling Third and final stage of biofouling that is characterised by the presence of sponges, ascidians, mussels, oysters, clams, gastropods, crabs, shrimp, seastars, sabellid worms, sea anemones and macroalgae.

Translocation The movement of an organism from one place to another.

Transport pressure Number of vessels arriving from a particular bioregion multiplied by a port duration weighting. This number is then summed within each of the 18 bioregions. For each species, the weighted number of vessels arriving from all bioregions where the species is present is summed, providing a cumulative number of vessel opportunities for that species to be transported into Australia. This value is then divided by the unweighted number of vessels entering Australia to provide the percentage of total opportunities for entry.

Vagility The distance moved by an organism; the ease with which an organism moves away from its place of birth.

Vector The physical means, agent or mechanism which facilitates the transfer of organisms or their propagules from one place to another. In a marine biosecurity context, this includes ships' ballast water, ships' hulls, movements of commercial oysters, and live seafood.

Vessel Any ship, barge, mobile drilling unit, work boat, craft, launch, submersible, etc

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APPENDIX A

Table A1: Habitat impacts from non-indigenous marine species**.**

NEGLIGIBLE TO VERY LOW	
•	No significant changes to habitat types observed; no new habitat type observed in the invaded area; populations of habitat-forming species are not affected (<1% change); non-indigenous marine species impacts affecting <1% of area of each habitat type.
•	Changes in habitat not measurable against background variability.
LOW	
•	Localised affects on habitat in <10% of total habitat area; measurable changes to habitat types; new habitat type observed; <10% reduction in population abundances of habitat-forming species.
•	In the absence of further impact, recovery is expected in days to months; no loss of habitat-forming species populations.
MODERATE	
•	<30% of habitat area affected/removed; moderate changes to habitat types; new habitat type(s) observed; possible loss of habitat type; <30% reduction in population abundances of habitat-forming species.
•	Impacts occurring at a local to national scale.
•	If no further impact is experienced, recovery is expected in years to decades; no loss of habitat-forming species.
HIGH	
•	Limited information is available on the identity and distribution of habitat types; limited information is available on the identity of habitat-forming species and their susceptibility to non-indigenous marine species.
•	<70% of habitat area affected/removed; major changes to habitat types; new habitat types observed; loss of most pre-existing habitat types; <70% reduction in population abundances of habitat-forming species; local extinction of at least one habitat-forming species.
•	Impacts occurring at a national scale.
•	If no further impact is experienced, recovery is expected in centuries; loss of habitat types and habitat-forming species; local extinction events.
EXTREME	
•	>70% of habitat area affected/removed; significant changes to habitat types; no pre-existing habitat types existing; >70% reduction in population abundances of habitat-forming species; local extinction of more than one habitat-forming species; global extinction of one habitat-forming species.
•	Impacts occurring at national and international scales.
•	If no further impact is experienced, recovery is not expected; loss of multiple habitat types and habitat-forming species populations causing significant local extinction; global extinction of at least one species.

Table A2: Biodiversity impacts from non-indigenous marine species.

NEGLIGIBLE TO VERY LOW	
•	Biodiversity impacted by non-indigenous marine species is small (<10%) compared to total impact by other hazards.
•	Impacts occurring at a local scale.
•	Reductions in species' richness and composition are not readily detectable (<10% variation).
•	In the absence of further impact, recovery is expected within days; no change in species' richness or composition.
LOW	
•	Biodiversity impacted by non-indigenous marine species is <20% compared to total impact by other hazards.
•	Impacts occurring at a local scale.
•	Reductions in species' richness and composition are <20%.
•	Biodiversity impacted and area of impact by non-indigenous marine species is small compared to known areas of distribution (<20%).
•	If no further impact is experienced, recovery is expected in days to months; no loss of species populations; no local extinctions.
MODERATE	
•	Biodiversity impacted by non-indigenous marine species is <30% compared to total impact by other hazards.
•	Impacts occurring at a national scale.
•	Reductions in species' richness and composition are <30%.
•	Biodiversity and area of impact by non-indigenous marine species is moderate compared to known area of distribution (<30%).
•	If no further impact is experienced, recovery is expected in years to decades; loss of at least one species or population; local extinction events.
HIGH	
•	Limited information is available on the distribution of the biodiversity relative to the non-indigenous marine species distribution; limited information is available on the susceptibility to non-indigenous marine species or the vulnerability of life history stages of these species.
•	Impacts occurring at a national scale.
•	Biodiversity impacted by non-indigenous marine species is <70% compared to total impact by other hazards.
•	Reductions in species' richness and composition are <70%.
•	Biodiversity and area of impact by non-indigenous marine species is small compared to known area of distribution (<70%); likely to cause local extinction.
•	If no further impact is required, recovery is expected in centuries; loss of several species or populations; multiple local extinction events; one regional extinction.
EXTREME	
•	Impacts occurring at national and international scales.
•	Biodiversity impacted by non-indigenous marine species is >70% compared to total impact by other hazards.
•	Reductions in species richness and composition are >70%.
•	Biodiversity and area impacted by non-indigenous marine species is small compared to known area of distribution (>70%); likely to cause local extinction.
•	Even if no further impact is experienced, recovery is not expected; loss of multiple species of populations causing significant local extinctions; global extinction of at least one species.

Table A3: Trophic interactions (ecosystem) impacts from non-indigenous marine species.

NEGLIGIBLE TO VERY LOW	
•	No significant changes in trophic level species composition observed; no change in relative abundance of trophic levels (based on biomass).
•	Changes in trophic interactions not measurable against background variability.
LOW	
•	Minor changes (<10%) in relative abundance of trophic levels (based on biomass); <10% reduction of population abundances for top predator species.
•	Impacts occurring at local scale.
•	In the absence of further impact, recovery is expected in days to months; no loss of keystone species populations.
MODERATE	
•	Measurable changes (<30%) in relative abundance of trophic levels (based on biomass); <30% reduction of population abundances for top predator species.
•	Impacts occurring at national scale.
•	If no further impact is experienced, recovery is expected in years to decades; loss of keystone species populations; no loss of primary producer populations.
HIGH	
•	Limited information is available on the species composition and abundances of trophic levels; limited information is available on the trophic interactions and fundamental ecosystem processes.
•	Impacts occurring at national scale.
•	Major changes (<70%) in relative abundance of trophic levels (based on biomass); <70% reduction of population abundances for top predator species; <30% reduction of population abundances for primary producer species.
•	If no further impact is experienced, recovery is expected in centuries; loss of keystone species populations; changes in trophic levels; loss of primary producer populations; local extinction events.
EXTREME	
•	Impacts occurring at national and international scales.
•	>70% change in relative abundance of trophic levels (based on biomass); >70% reduction of population abundances for top predator species; >30% reduction of population abundances for primary producer species.
•	Even if no further impact is experienced, recovery is not expected; loss of trophic levels; potential trophic cascades resulting in significant changes to ecosystem structure; alteration of biodiversity patterns and changes to ecosystem function; significant local extinctions.

APPENDIX A

Table A4: Nationally important and ecologically valuable species impacts from non-indigenous marine species.

NEGLIGIBLE TO VERY LOW	
•	No nationally important and/or ecologically valuable species impacted by non-indigenous marine species; impacts on behaviour not detectable.
•	In the absence of further impact, recovery is expected; no loss of nationally important and/or ecologically valuable individuals.
LOW	
•	Nationally important and/or ecologically valuable species impacted by non-indigenous marine species is <1% compared to impact from other hazards.
•	Reductions in nationally important and/or ecologically valuable species population abundances are <1%.
•	If no further impact is experienced, recovery is expected in months to years; no loss of nationally important and/or ecologically valuable species populations.
MODERATE	
•	Nationally important and/or ecologically valuable species impacted by non-indigenous marine species is <10% compared to impact from other hazards.
•	Reductions in nationally important and/or ecologically valuable species population abundances are <10%.
•	If no further impact is experienced, recovery is expected in years to decades; no loss of nationally important and/or ecologically valuable species populations; potential loss of genetic diversity.
HIGH	
•	Limited information is available on: distribution and behaviour of nationally important and/or ecologically valuable species relative to the region; and susceptibility to impact or the behavioural vulnerability of the nationally important and/or ecologically valuable species.
•	Nationally important and/or ecologically valuable species impacted by non-indigenous marine species is <20% compared to impact from other hazards.
•	Reductions in nationally important and/or ecologically valuable species population abundances are <20%.
•	If no further impact is experienced, recovery is expected in centuries; loss of nationally important and/or ecologically valuable species populations causing local extinction; measurable loss of genetic diversity.
EXTREME	
•	Nationally important and/or ecologically valuable species impacted by non-indigenous marine species is >20% compared to impact from other hazards.
•	Reductions in nationally important and/or ecologically valuable species population abundances are significant, i.e. >20%.
•	Even in the absence of further impact, recovery is not expected; loss of nationally important and/or ecologically valuable species populations causing global extinction; local extinction of multiple nationally important and/or ecologically valuable species; significant loss of genetic diversity of multiple nationally important and/or ecologically valuable species.

APPENDIX A

Table A5: Assets of environmental significance impacts from non-indigenous marine species.

NEGLIGIBLE TO VERY LOW	
•	No significant changes to assets of environmental significance.
•	Changes in assets of environmental significance not measurable against background variability.
LOW	
•	Localised affects on assets of environmental significance in <10% of total asset area; measurable changes to assets of environmental significance; <10% reduction in intrinsic value of assets of environmental significance.
•	If no further impact is experienced, recovery is expected in days to months; no loss of assets of environmental significance.
MODERATE	
•	<30% of assets of environmental significance affected or removed; moderate changes to assets of environmental significance; possible loss of assets; <30% reduction in intrinsic value of assets of environmental significance.
•	If no further impact is experienced, recovery is expected in years to decades; no loss of assets of environmental significance.
HIGH	
•	Limited information is available on the assets of environmental significance and their susceptibility to non-indigenous marine species.
•	<70% of assets of environmental significance affected or removed; major changes to assets of environmental significance; <70% reduction in intrinsic value of the asset(s); loss of at least one asset of environmental significance.
•	If no further impact is experienced, recovery is expected in centuries; loss of assets of environmental significance.
EXTREME	
•	>70% of assets of environmental significance affected or removed; significant changes to assets of environmental significance; local extinction of more than one asset of environmental significance; global extinction of one asset of environmental significance.
•	Reductions in nationally important and/or ecologically valuable species population abundances are significant, i.e. >20%.
•	Even if no further impact is experienced, recovery is not expected; loss of multiple assets of environmental significance causing significant local extinction; global extinction of at least one species.

APPENDIX A

Table A6: Economic impacts from non-indigenous marine species.

NEGLIGIBLE TO VERY LOW	
•	No discernible reduction in national income (including access to international markets and/or trade) from non-indigenous marine species impact.
•	No discernible reduction in regional income from non-indigenous marine species impact.
•	No discernable change in strength of economic activities.
•	No damage or deterioration of infrastructure used by a significant proportion of people (>80% of local population) over a local area.
•	If the non-indigenous marine species was removed, recovery is expected within days.
LOW	
•	Reduction in national income (including access to international markets and/or trade) from non-indigenous marine species impact is <1%.
•	Reduction in regional income from non-indigenous marine species impact is <30%.
•	Reduction of strength in individual economic activities is <1%.
•	Economic activity is reduced to 99% of its original area (spatial context) within Australia.
•	<10% damage or deterioration of infrastructure used by a significant proportion of people (>80% of local population) across a local area.
•	If the non-indigenous marine species was removed, recovery is expected in days to months, with no loss of any economic industry.
MODERATE	
•	Reduction in national income (including access to international markets and/or trade) from non-indigenous marine species impact is 1-5%.
•	Reduction in regional income from non-indigenous marine species impact is 30-50%.
•	Reduction of strength in individual economic activities is 1-5%.
•	Economic activity is reduced to less than 95% of its original area (spatial context) within Australia.
•	<30 per cent or deterioration of infrastructure used by a significant proportion of people (>80% of local population) across a regional area.
•	If the non-indigenous marine species was removed, recovery is expected in less than a year with the loss of at least one economic activity.
HIGH	
•	Reduction in national income (including access to international markets and/or trade) from non-indigenous marine species impact is 5-10%.
•	Reduction in regional income from non-indigenous marine species impact is 50-70%.
•	Reduction of strength in individual economic activities is 5-10%.
•	Economic activity is reduced to less than 90% of its original area (spatial context) within Australia.
•	<70% damage or deterioration of infrastructure used by a significant proportion of people (>80% of local population) across a nation.
•	If the non-indigenous marine species was removed, recovery is expected in less than a decade and at least one economic activity would be lost.
EXTREME	
•	Reduction in national income (including access to international markets and/or trade) from non-indigenous marine species impact is >10%.
•	Reduction in regional income from non-indigenous marine species impact is>70%.
•	Reduction of strength in individual economic activities is >10%.
•	Economic activity is reduced to less than 90 per cent of its original area (spatial context) within the Australia.
•	>70% damage or deterioration of infrastructure used by a significant proportion of people (>80% of local population) across a nation, or across international borders.
•	If the non-indigenous marine species was removed, recovery is not expected and loss of muliple economic activities is anticipated.

Table A7: Social impacts from non-indigenous marine species.

NEGLIGIBLE TO VERY LOW
• Social activity reduction is minimal (<1%).
• Degradation of amenity used by 80% of people across a local scale is minimal (<1%).
• No significant changes to nationally important places.
• No discernable change in strength of social activities.
• If the non-indigenous marine species was removed, recovery is expected within days.
LOW
• Social activity reduction is <10%.
• <10% degradation of amenity used by 80% of people across a local scale.
• Localised effects on <10% of nationally important places; measurable changes to nationally important places; <10% reduction in intrinsic value of nationally important places.
• Reduction of strength in separate social activities is <10%.
• Social activity is reduced to less than 90% of its original area (spatial context) within the region.
• If the non-indigenous marine species was removed, recovery is expected in days to months, with no loss of any social activities.
MODERATE
• Social activity reduction is <20%.
• <30% degradation of amenity used by 80% of people across a regional scale.
• <30% of nationally important places affected; moderate changes to nationally important places; <30% reduction in intrinsic value of nationally important places.
• Reduction of strength in separate social activities is <20%.
• Social activity is reduced to less than 80% of its original area (spatial context) within the region.
• Social activity reduction is restricted to the region of incursion/impact.
• If the non-indigenous marine species was removed recovery is expected in less than a year and loss of at least one tourism activity is anticipated.
HIGH
• Social activity reduction is <40%.
• <70% degradation of amenity used by 80% of people across a nation.
• <70% of nationally important places affected; major changes to nationally important places; <70% reduction in intrinsic value of the nationally important places; loss of at least one nationally important place.
• Reduction of strength in separate social activities is <40%.
• Social activity is reduced to less than 70% of its original area (spatial context) within the region.
• Social activity is reduced in neighbouring regions.
• If the non-indigenous marine species was removed, recovery is expected in less than a decade and loss of at least one tourism activity is anticipated.
EXTREME
• Social activity reduction is >40%.
• >70% degradation of amenity used by 80% of people across a nation, or across international borders.
• >70% of nationally important places affected; significant changes to nationally important places; loss of more than one nationally important place.
• Reduction of strength in separate social activities is >40%.
• Social activity is reduced to less than 60% of its original area (spatial context) within the region.
• Social activity is reduced in neighbouring countries.
• If the non-indigenous marine species was removed, recovery is not expected and loss of multiple tourism activities is anticipated.

Table A8: Cultural impacts from non-indigenous marine species.

NEGLIGIBLE TO VERY LOW
• Cultural activity reduction is minimal (<1%).
• Degradation of cultural amenities used by 80% of people across a local scale is minimal (<1%).
• No significant changes to culturally important places.
• No discernable change in strength of cultural activities.
• If the non-indigenous marine species was removed, recovery is expected within days.
LOW
• Cultural activity reduction is <10%.
• <10% degradation of cultural amenities used by 80% of people across a local scale.
• Localised affects on <10% of culturally important places; measurable changes to culturally important places; <10% reduction in intrinsic value of culturally important places.
• Reduction of strength in separate cultural activities is <10%.
• Cultural activity is reduced to less than 90% of its original area (spatial context) within the region.
• If the non-indigenous marine species was removed, recovery is expected in days to months, with no loss of social activities.
MODERATE
• Cultural activity reduction is <20%.
• <30% degradation of cultural amenities used by 80% of people across a regional scale.
• <30% of culturally important places affected; moderate changes to nationally important places; <30% reduction in intrinsic value of culturally important places.
• Reduction of strength in separate cultural activities is <20%.
• Cultural activity is reduced to less than 80% of its original area (spatial context) within the region.
• Cultural activity reduction is restricted to the region of incursion/impact.
• If the non-indigenous marine species was removed, recovery is expected in less than a year and loss of at least one tourism activity is anticipated.
HIGH
• Cultural activity reduction is <40%.
• <70% degradation of cultural amenities used by 80% of people across a nation.
• <70% of culturally important places affected; major changes to culturally important places; <70% reduction in intrinsic value of the culturally important places; loss of at least one culturally important place.
• Reduction of strength in separate cultural activities is <40%.
• Cultural activity is reduced to less than 70% of its original area (spatial context) within the region.
• Cultural activity is reduced in neighbouring regions.
• If the non-indigenous marine species was removed, recovery is expected in less than a decade and loss of at least one tourism activity is anticipated.
EXTREME
• Cultural activity reduction is >40%.
• >70% degradation of cultural amenities used by 80% of people across a nation, or across international borders.
• >70% of culturally important places affected; significant changes to culturally important places; loss of more than one culturally important place.
• Reduction of strength in separate cultural activities is >40%.
• Cultural activity is reduced to less than 60% of its original area (spatial context) within the region.
• Cultural activity is reduced in neighbouring countries.
• If the non-indigenous marine species was removed, recovery is not expected and loss of multiple tourism activities is anticipated.

APPENDIX A

Table A9: National image impacts from non-indigenous marine species.

NEGLIGIBLE TO VERY LOW	
•	National image reduction is minimal (<1%).
•	No significant changes to nationally important places.
•	No discernable change in strength of national image.
•	If the non-indigenous marine species was removed, recovery is expected within days.
LOW	
•	National image activity reduction is <10%.
•	Localised affects on <10% of nationally important places; measurable changes to nationally important places; <10% reduction in intrinsic value of nationally important places.
•	Reduction of strength in separate national image activities is <10%.
•	National image activity is reduced to less than 90% of its original area (spatial context) within the region.
•	If the non-indigenous marine species was removed, recovery is expected in days to months, with no loss of any social activities.
MODERATE	
•	National image activity reduction is <20%.
•	<30% of nationally important places affected; moderate changes to nationally important places; <30% reduction in intrinsic value of nationally important places.
•	Reduction of strength in separate national image activities is <20%.
•	National image activity is reduced to less than 80% of its original area (spatial context) within the region.
•	National image activity reduction is restricted to the region of incursion/impact.
•	If the non-indigenous marine species was removed, recovery is expected in less than a year and loss of at least one tourism activity is anticipated.
HIGH	
•	National image activity reduction is <40%.
•	<70% of nationally important places affected; major changes to nationally important places; <70% reduction in intrinsic value of nationally important places; loss of at least one nationally important place.
•	Reduction of strength in separate national image activities is <40%.
•	National image activity is reduced to less than 70% of its original area (spatial context) within the region.
•	National image activity is reduced in neighbouring regions.
•	If the non-indigenous marine species was removed, recovery is expected in less than a decade and loss of at least one tourism activity is anticipated.
EXTREME	
•	National image activity reduction is >40%.
•	>70% of nationally important places affected; significant changes to nationally important places; loss of more than one nationally important place.
•	Reduction of strength in separate national image activities is >40%.
•	National image activity is reduced to less than 60% of its original area (spatial context) within the region.
•	National image is reduced in neighbouring countries.
•	If the non-indigenous marine species was removed, recovery is not expected and loss of multiple tourism activities is anticipated.

APPENDIX A

Table A10: Aesthetic impacts from non-indigenous marine species.

NEGLIGIBLE TO VERY LOW	
•	Aesthetic appeal reduction is minimal (<1%).
•	No discernable change in strength of aesthetic appeal.
•	If the non-indigenous marine species was removed, recovery is expected within days.
LOW	
•	Aesthetic appeal reduction is <10%.
•	Localised affects on aesthetics in <10% of nationally important places; measurable changes to nationally important places; <10% reduction in intrinsic value of nationally important places.
•	Reduction of strength in separate aesthetic appeal is <10%.
•	Aesthetic appeal is reduced in localised regions.
•	If the non-indigenous marine species was removed, recovery is expected in days to months, with no loss of social activities.
MODERATE	
•	Aesthetic appeal reduction is <20%.
•	Reduction of strength in separate aesthetic appeal is <20%.
•	Aesthetic appeal is reduced in neighbouring regions.
•	If the non-indigenous marine species was removed, recovery is expected in less than a year and loss of at least one tourism activity is anticipated.
HIGH	
•	Aesthetic appeal reduction is <40%.
•	Reduction of strength in separate aesthetic appeal is <40%.
•	Aesthetic appeal is reduced in national regions.
•	If the non-indigenous marine species was removed, recovery is expected in less than a decade and loss of at least one tourism activity is anticipated.
EXTREME	
•	Aesthetic appeal reduction is >40%.
•	Reduction of strength in separate aesthetic appeal is >40%.
•	Aesthetic appeal is reduced to less than 60% of its original area (spatial context) within the region.
•	Aesthetic appeal is reduced in national and international regions.
•	If the non-indigenous marine species was removed, recovery is not expected and loss of multiple tourism activities is anticipated.

Table A11: Human health impacts from non-indigenous marine species.

NEGLIGIBLE TO VERY LOW	
•	No discernible impact on human health (nuisance level).
•	No discernible increase in human morbidity.
•	No discernible increase in human mortality.
•	No discernible decrease in quality of life.
•	If the non-indigenous marine species was removed, recovery is expected within days.
LOW	
•	Impact on human health (nuisance level) is <10% across a localised area.
•	<10% impact on human morbidity in a localised area.
•	No discernible increase in human mortality.
•	<10% decreases in quality of life in a localised area.
•	If the non-indigenous marine species was removed, recovery is expected in days to months, with no loss of human life experienced.
MODERATE	
•	Impact on human health (nuisance level) is <30% across a localised area.
•	<30% impact on human morbidity in a localised area.
•	No discernible increase in human mortality.
•	<30% decrease in quality of life in a localised area.
•	If the non-indigenous marine species was removed, recovery is expected in less than a year, with no loss of human life experienced.
HIGH	
•	Impact on human health (nuisance level) is <70% in a national area.
•	<70% impact on human morbidity in a national area.
•	Localised increase in human mortality (<1%).
•	<70% decrease in quality of life in a national area.
•	If the non-indigenous marine species was removed, recovery is expected in less than a decade and loss of at least one human life at a national level is anticipated.
EXTREME	
•	Impact on human health (nuisance level) >70% in a national and international area.
•	>70% impact on human morbidity in a national and international area.
•	National increase in human mortality (<10%).
•	>70% decrease in quality of life in national and international areas.
•	If the non-indigenous marine species was removed, recovery is not expected and loss of multiple human lives across international borders is anticipated.

Table B1: Species list with likelihood ranks for biofouling association and transport pressure based on all voyage durations (LPOC, 30d, 60d, 90d, 183d, or 365d) between 2002 and 2007.

PHYLUM	GENUS SPECIES	BIOFOULING ASSOCIATION RANK	TRANSPORT PRESSURE RANK	INOCULATION LIKELIHOOD
Annelida	*Hydroides dianthus*	High	Low	Moderate
Annelida	*Marenzelleria neglecta*	Negligible	Extremely Low	Extremely Low
Annelida	*Marenzelleria viridis*	Negligible	Very Low	Extremely Low
Annelida	*Polydora nuchalis*	Low	Very Low	Low
Arthropoda	*Acartia tonsa*	Low	Low	Low
Arthropoda	*Ampelisca abdita*	Low	Low	Low
Arthropoda	*Balanus eburneus*	High	High	High
Arthropoda	*Balanus glandula*	High	Moderate	High
Arthropoda	*Balanus improvisus*	High	High	High
Arthropoda	*Briarosaccus callosus*	Low	Moderate	Moderate
Arthropoda	*Callinectes bocourti*	Very Low	Extremely Low	Very Low
Arthropoda	*Callinectes sapidus*	Very Low	Moderate	Low
Arthropoda	*Carcinoscorpius rotundicauda*	Very Low	High	Low
Arthropoda	*Charybdis japonica*	Moderate	Low	Moderate
Arthropoda	*Chthamalus proteus*	High	Low	Moderate
Arthropoda	*Crangonyx floridanus*	Very Low	Low	Low
Arthropoda	*Dikerogammarus haemobaphes*	Low	Negligible	Very Low
Arthropoda	*Dikerogammarus villosus*	Low	Extremely Low	Very Low
Arthropoda	*Echinogammarus berilloni*	Low	Extremely Low	Very Low
Arthropoda	*Echinogammarus ischnus*	Low	Extremely Low	Very Low
Arthropoda	*Eriocheir sinensis*	Moderate	Moderate	Moderate
Arthropoda	*Gammarus tigrinus*	Moderate	Extremely Low	Low
Arthropoda	*Gmelinoides fasciatus*	Low	Low	Low
Arthropoda	*Hemigrapsus penicillatus*	Moderate	Low	Moderate
Arthropoda	*Hemigrapsus sanguineus*	Low	Moderate	Moderate
Arthropoda	*Homarus americanus*	Negligible	Very Low	Extremely Low
Arthropoda	*Loxothylacus panopaei*	Low	Extremely Low	Very Low

APPENDIX B: (TABLE B1: 2/6)

Table B1: Species list with likelihood ranks for biofouling association and transport pressure based on all voyage durations (LPOC, 30d, 60d, 90d, 183d, or 365d) between 2002 and 2007.

PHYLUM	GENUS SPECIES	BIOFOULING ASSOCIATION RANK	TRANSPORT PRESSURE RANK	INOCULATION LIKELIHOOD
Arthropoda	*Pachygrapsus fakaravensis*	Moderate	Extremely Low	Low
Arthropoda	*Palaemon elegans*	Low	Extremely Low	Very Low
Arthropoda	*Paramysis lacustris*	Low	Extremely Low	Very Low
Arthropoda	*Pontogammarus robustoides*	Low	Extremely Low	Very Low
Arthropoda	*Pseudodiaptomus forbesi*	Low	Low	Low
Arthropoda	*Pseudodiaptomus inopinus*	Low	Low	Low
Arthropoda	*Pseudodiaptomus marinus*	Low	Moderate	Moderate
Arthropoda	*Rhithropanopeus harrisi*	Moderate	Moderate	Moderate
Arthropoda	*Sinocalanus doerii*	Low	Low	Very Low
Arthropoda	*Solidobalanus fallax*	Low	Very Low	Low
Arthropoda	*Sphaeroma annandalei*	Low	Very Low	Low
Arthropoda	*Sylon hippolytes*	Low	Moderate	Moderate
Arthropoda	*Tortanus dextrilobatus*	Low	Moderate	Moderate
Bacillariophyta	*Chaetoceros concavicornis*	Extremely Low	Moderate	Low
Bacillariophyta	*Chaetoceros convolutus*	Extremely Low	Moderate	Low
Bacillariophyta	*Corethron criophilum*	Negligible	Extremely Low	Extremely Low
Bacillariophyta	*Coscinodiscus wailesii*	Extremely Low	High	Low
Bacillariophyta	*Odontella (Biddulphia) sinensis*	Extremely Low	Very Low	Very Low
Bacillariophyta	*Pseudo-nitzschia seriata*	Extremely Low	Extremely Low	Very Low
Chlorophycota	*Avrainvillea amadelpha*	Low	Low	Low
Chlorophycota	*Codium fragile atlanticum*	Very Low	Moderate	Low
Chlorophycota	*Codium fragile scandinavicum*	Very Low	Extremely Low	Very Low
Chlorophycota	*Enteromorpha clathrata*	High	Extremely Low	Very Low
Chlorophycota	*Monostroma obscurum*	Low	Extremely Low	Very Low
Chlorophycota	*Ulva pertusa*	High	Low	Moderate

APPENDIX B: (TABLE B1: 3/6)

Table B1: Species list with likelihood ranks for biofouling association and transport pressure based on all voyage durations (LPOC, 30d, 60d, 90d, 183d, or 365d) between 2002 and 2007.

PHYLUM	GENUS SPECIES	BIOFOULING ASSOCIATION RANK	TRANSPORT PRESSURE RANK	INOCULATION LIKELIHOOD
Chordata	*Botrylloides simodensis*	High	Low	Moderate
Chordata	*Ciona savignyi*	Low	Moderate	Moderate
Chordata	*Clavelina lepadiformis*	High	Very Low	Low
Chordata	*Didemnum lahillei*	Low	Moderate	Moderate
Chordata	*Didemnum perlucidum*	Low	Moderate	Moderate
Chordata	*Didemnum vexillum*	High	Moderate	High
Chordata	*Neogobius melanostomus*	Low	Extremely Low	Very Low
Chordata	*Polyandrocarpa zorritensis*	Low	Moderate	Moderate
Chordata	*Siganus luridus*	Very Low	Extremely Low	Very Low
Chordata	*Siganus rivulatus*	Very Low	Very Low	Very Low
Chordata	*Symplegma reptans*	Low	High	Moderate
Chordata	*Tridentiger barbatus*	Low	Low	Low
Chordata	*Tridentiger bifasciatus*	Low	Low	Low
Cnidaria	*Aiptasia pulchella*	Low	Moderate	Moderate
Cnidaria	*Aurelia aurita*	Negligible	High	Very Low
Cnidaria	*Blackfordia virginica*	Low	Very Low	Low
Cnidaria	*Cassiopea andromeda*	Negligible	Low	Very Low
Cnidaria	*Diadumene lineata*	Low	High	Moderate
Cnidaria	*Gonionemus vertens*	Low	Low	Low
Cnidaria	*Maeotias marginata*	Low	Very Low	Low
Cnidaria	*Moerisia lyonsi*	Low	Extremely Low	Very Low
Cnidaria	*Muggiaea atlantica*	Negligible	Very Low	Extremely Low
Cnidaria	*Rathkea octopunctata*	Low	Extremely Low	Very Low
Cnidaria	*Rhopilema nomadica*	Negligible	Extremely Low	Extremely Low
Cnidaria	*Sagartia elegans*	Low	Extremely Low	Very Low
Cnidaria	*Sagartia ornata*	Low	Extremely Low	Very Low
Cnidaria	*Sarsia tubulosa*	Low	Very Low	Low

Table B1: Species list with likelihood ranks for biofouling association and transport pressure based on all voyage durations (LPOC, 30d, 60d, 90d, 183d, or 365d) between 2002 and 2007.

PHYLUM	GENUS SPECIES	BIOFOULING ASSOCIATION RANK	TRANSPORT PRESSURE RANK	INOCULATION LIKELIHOOD
Cnidaria	*Thyroscyphus fruticosus*	Moderate	Low	Moderate
Cnidaria	*Tiaropsis multicirrata*	Low	Very Low	Very Low
Ctenophora	*Mnemiopsis leidyi*	Negligible	Extremely Low	Extremely Low
Echinodermata	*Asterina wega*	Very Low	Extremely Low	Very Low
Ectoprocta	*Buskia nitens*	Low	Moderate	Moderate
Ectoprocta	*Membranipora tenuis*	Low	Extremely Low	Very Low
Ectoprocta	*Pectinatella magnifica*	Low	Low	Low
Ectoprocta	*Sundanella sibogae*	Low	Extremely Low	Very Low
Entoprocta	*Loxosomatoides laevis*	Low	Extremely Low	Very Low
Heterokontophyta	*Chattonella antiqua*	Extremely Low	Low	Very Low
Heterokontophyta	*Fucus evanescens*	Low	Low	Low
Heterokontophyta	*Pseudochattonella farcimen*	Extremely Low	Extremely Low	Very Low
Heterokontophyta	*Sargassum muticum*	High	High	High
Mollusca	*Anadara demiri*	Low	Very Low	Low
Mollusca	*Anomia nobilis*	High	Low	Moderate
Mollusca	*Brachidontes variabilis*	High	Low	Moderate
Mollusca	*Cerithium scabridum*	Low	Very Low	Low
Mollusca	*Corbicula fluminea*	Very Low	Moderate	Low
Mollusca	*Crassostrea ariakensis*	Low	Low	Low
Mollusca	*Crassostrea virginica*	High	Low	Moderate
Mollusca	*Crepidula fornicata*	Moderate	Moderate	Moderate
Mollusca	*Crepidula lingulata*	Moderate	Low	Moderate
Mollusca	*Crucibulum spinosum*	Low	Very Low	Low
Mollusca	*Dreissena bugensis*	High	Extremely Low	Low
Mollusca	*Dreissena polymorpha*	High	Extremely Low	Low
Mollusca	*Ensis directus*	Very Low	Very Low	Very Low
Mollusca	*Geukensia demissa*	Low	Extremely Low	Very Low

Table B1: Species list with likelihood ranks for biofouling association and transport pressure based on all voyage durations (LPOC, 30d, 60d, 90d, 183d, or 365d) between 2002 and 2007.

PHYLUM	GENUS SPECIES	BIOFOULING ASSOCIATION RANK	TRANSPORT PRESSURE RANK	INOCULATION LIKELIHOOD
Mollusca	*Limnoperna fortunei*	Moderate	Low	Moderate
Mollusca	*Lithoglyphus naticoides*	Low	Extremely Low	Very Low
Mollusca	*Mactra nitida*	Very Low	Extremely Low	Very Low
Mollusca	*Melibe viridis*	Very Low	Very Low	Very Low
Mollusca	*Meretrix lusoria*	Low	Extremely Low	Very Low
Mollusca	*Mya arenaria*	Very Low	Very Low	Very Low
Mollusca	*Mytella charruana*	Low	Extremely Low	Very Low
Mollusca	*Mytilopsis leucophaeta*	High	Moderate	High
Mollusca	*Mytilopsis sallei*	High	High	High
Mollusca	*Perna perna*	High	Low	Moderate
Mollusca	*Perna viridis*	High	High	High
Mollusca	*Corbula (Potamocorbula) amurensis*	Very Low	Low	Low
Mollusca	*Pyrgophorus coronatus*	Low	Extremely Low	Very Low
Mollusca	*Rapana venosa (thomasiana)*	Very Low	Moderate	Low
Mollusca	*Sabia conica*	Low	Very Low	Low
Mollusca	*Siphonaria pectinata*	Low	Extremely Low	Very Low
Mollusca	*Tarebia granifera*	Low	Extremely Low	Very Low
Mollusca	*Tenellia adspersa*	Moderate	Low	Moderate
Mollusca	*Tritonia plebeia*	Low	Extremely Low	Very Low
Mollusca	*Viviparus georgianus*	Low	Extremely Low	Very Low
Nematoda	*Anguillicola crassus*	Negligible	Low	Very Low
Nematoda	*Camallanus cotti*	Negligible	Low	Very Low
Porifera	*Cliona thoosina*	Low	Very Low	Low
Porifera	*Eunapius carteri*	Low	Low	Low
Porifera	*Gelliodes fibrosa*	Low	Low	Low
Protozoa	*Bonamia ostreae*	Low	Very Low	Low
Pyrrophycophyta	*Alexandrium monilatum*	Extremely Low	Very Low	Very Low

APPENDIX B: (TABLE B1: 6/6)

Table B1: Species list with likelihood ranks for biofouling association and transport pressure based on all voyage durations (LPOC, 30d, 60d, 90d, 183d, or 365d) between 2002 and 2007.

PHYLUM	GENUS SPECIES	BIOFOULING ASSOCIATION RANK	TRANSPORT PRESSURE RANK	INOCULATION LIKELIHOOD
Pyrrophycophyta	*Dinophysis norvegica*	Extremely Low	Moderate	Low
Pyrrophycophyta	*Pfiesteria piscicida*	Extremely Low	Extremely Low	Very Low
Rhodophycota	*Acrochaetium balticum*	Low	Extremely Low	Very Low
Rhodophycota	*Aglaothamnion halliae*	High	Very Low	Low
Rhodophycota	*Antithamnion densum*	Low	Very Low	Low
Rhodophycota	*Antithamnion nipponicum*	Low	Moderate	Moderate
Rhodophycota	*Antithamnionella elegans*	Low	Low	Low
Rhodophycota	*Antithamnionella sublittoralis*	Low	Very Low	Low
Rhodophycota	*Asparagopsis armata*	High	Low	Moderate
Rhodophycota	*Bonnemaisonia hamifera*	High	Very Low	Low
Rhodophycota	*Caulacanthus ustulatus*	Low	Very Low	Low
Rhodophycota	*Chondrus giganteus*	Low	Low	Low
Rhodophycota	*Chrysymenia wrightii*	Low	Low	Low
Rhodophycota	*Dasya sessilis*	Low	Extremely Low	Very Low
Rhodophycota	*Gracilaria tikvahiae*	Low	Extremely Low	Very Low
Rhodophycota	*Gracilaria vermiculophylla*	Low	Low	Low
Rhodophycota	*Grateloupia doryphora*	High	Very Low	Low
Rhodophycota	*Heterosiphonia japonica*	High	Moderate	High
Rhodophycota	*Hypnea musciformis*	High	Low	Moderate
Rhodophycota	*Kappaphycus alvarezii*	Low	Low	Low
Rhodophycota	*Kappaphycus striatum*	Low	Low	Low
Rhodophycota	*Lithophyllum yessoense*	Low	Very Low	Low
Rhodophycota	*Lophocladia lallemandii*	Low	Extremely Low	Very Low
Rhodophycota	*Mastocarpus stellatus*	Low	Extremely Low	Very Low
Rhodophycota	*Polysiphonia breviarticulata*	High	Very Low	Low
Rhodophycota	*Polysiphonia harveyi*	High	Moderate	High
Rhodophycota	*Polysiphonia morrowii*	High	Low	Moderate
Rhodophycota	*Polysiphonia nigrescens*	High	Very Low	Low
Rhodophycota	*Womersleyella setacea*	High	Low	Moderate

Table B2: Species list with consequence ranks and risks for Environmental (ENV), Economic (ECON), Social/Cultural (S/C) and Human health (HH) based on all voyage durations (LPOC, 30d, 60d, 90d, 183d, or 365d) between 2002 and 2007.

PHYLUM	GENUS SPECIES	ENV RANK	ECON RANK	S/C RANK	HH RANK	ENV RISK	ECON RISK	S/C RISK	HUMAN HEALTH RISK
Annelida	*Hydroides dianthus*	Negligible	Very Low	Negligible	Negligible	Low	Moderate	Low	Low
Annelida	*Marenzelleria neglecta*	Moderate	Negligible	Negligible	Negligible	Low	Very Low	Very Low	Very Low
Annelida	*Marenzelleria viridis*	Low	Moderate	Negligible	Negligible	Low	Low	Very Low	Very Low
Annelida	*Polydora nuchalis*	Negligible	High	Negligible	Negligible	Low	High	Low	Low
Arthropoda	*Acartia tonsa*	Moderate	Negligible	Negligible	Negligible	Moderate	Low	Low	Low
Arthropoda	*Ampelisca abdita*	Moderate	Negligible	Negligible	Negligible	Moderate	Low	Low	Low
Arthropoda	*Balanus eburneus*	High	Low	Negligible	Moderate	Extreme	Moderate	Low	High
Arthropoda	*Balanus glandula*	Moderate	Negligible	Negligible	Negligible	High	Low	Low	Low
Arthropoda	*Balanus improvisus*	Moderate	High	Negligible	Moderate	High	Extreme	Low	High
Arthropoda	*Briarosaccus callosus*	Negligible	High	Negligible	Negligible	Low	High	Low	Low
Arthropoda	*Callinectes bocourti*	Very Low	Negligible	Negligible	Negligible	Low	Very Low	Very Low	Very Low
Arthropoda	*Callinectes sapidus*	Negligible	High	Negligible	Negligible	Low	High	Low	Low
Arthropoda	*Carcinoscorpius rotundicauda*	Negligible	Negligible	Negligible	High	Low	Low	Low	High
Arthropoda	*Charybdis japonica*	Moderate	Extreme	Negligible	Extreme	High	Extreme	Low	Extreme
Arthropoda	*Chthamalus proteus*	Moderate	Negligible	Negligible	Negligible	High	Low	Low	Low
Arthropoda	*Crangonyx floridanus*	Moderate	Negligible	Negligible	Negligible	Moderate	Low	Low	Low
Arthropoda	*Dikerogammarus haemobaphes*	Very Low	Negligible	Negligible	Negligible	Low	Very Low	Very Low	Very Low
Arthropoda	*Dikerogammarus villosus*	Extreme	Negligible	Negligible	Negligible	Moderate	Very Low	Very Low	Very Low
Arthropoda	*Echinogammarus berilloni*	Low	Negligible	Negligible	Negligible	Low	Very Low	Very Low	Very Low
Arthropoda	*Echinogammarus ischnus*	Low	Negligible	Negligible	Negligible	Low	Very Low	Very Low	Very Low
Arthropoda	*Eriocheir sinensis*	High	High	High	High	High	High	High	High
Arthropoda	*Gammarus tigrinus*	Moderate	Negligible	Negligible	Negligible	Moderate	Low	Low	Low
Arthropoda	*Gmelinoides fasciatus*	High	Negligible	Negligible	Negligible	High	Low	Low	Low
Arthropoda	*Hemigrapsus penicillatus*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Arthropoda	*Hemigrapsus sanguineus*	High	Moderate	Negligible	Negligible	High	High	Low	Low
Arthropoda	*Homarus americanus*	Low	Moderate	Negligible	Negligible	Low	Low	Very Low	Very Low
Arthropoda	*Loxothylacus panopaei*	High	High	Negligible	Negligible	Moderate	Moderate	Very Low	Very Low

Table B2: Species list with consequence ranks and risks for Environmental (ENV), Economic (ECON), Social/Cultural (S/C) and Human health (HH) based on all voyage durations (LPOC, 30d, 60d, 90d, 183d, or 365d) between 2002 and 2007**.**

PHYLUM	GENUS SPECIES	ENV RANK	ECON RANK	S/C RANK	HH RANK	ENV RISK	ECON RISK	S/C RISK	HUMAN HEALTH RISK
Arthropoda	*Pachygrapsus fakaravensis*	Moderate	Negligible	Negligible	Negligible	Moderate	Low	Low	Low
Arthropoda	*Palaemon elegans*	Low	Negligible	Negligible	Low	Low	Very Low	Very Low	Low
Arthropoda	*Paramysis lacustris*	Low	Negligible	Negligible	Negligible	Low	Very Low	Very Low	Very Low
Arthropoda	*Pontogammarus robustoides*	Low	Negligible	Negligible	Negligible	Low	Very Low	Very Low	Very Low
Arthropoda	*Pseudodiaptomus forbesi*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Arthropoda	*Pseudodiaptomus inopinus*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Arthropoda	*Pseudodiaptomus marinus*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Arthropoda	*Rhithropanopeus harrisi*	Moderate	High	Negligible	Negligible	High	High	Low	Low
Arthropoda	*Sinocalanus doerii*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Arthropoda	*Solidobalanus fallax*	Extreme	Moderate	Negligible	Negligible	High	Moderate	Low	Low
Arthropoda	*Sphaeroma annandalei*	Extreme	Moderate	Negligible	Negligible	High	Moderate	Low	Low
Arthropoda	*Sylon hippolytes*	Negligible	High	Negligible	Negligible	Low	High	Low	Low
Arthropoda	*Tortanus dextrilobatus*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Bacillariophyta	*Chaetoceros concavicornis*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Bacillariophyta	*Chaetoceros convolutus*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Bacillariophyta	*Corethron criophilum*	Moderate	High	Negligible	Negligible	Low	Moderate	Very Low	Very Low
Bacillariophyta	*Coscinodiscus wailesii*	Negligible	High	Negligible	Negligible	Low	Low	Low	Low
Bacillariophyta	*Odontella (Biddulphia) sinensis*	Low	Negligible	Negligible	Negligible	Low	Very Low	Very Low	Very Low
Bacillariophyta	*Pseudo-nitzschia seriata*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Chlorophycota	*Avrainvillea amadelpha*	Moderate	Low	Negligible	Negligible	Moderate	Moderate	Low	Low
Chlorophycota	*Codium fragile atlanticum*	Moderate	Negligible	Negligible	Negligible	Moderate	Low	Low	Low
Chlorophycota	*Codium fragile scandinavicum*	Low	Negligible	Negligible	Negligible	Low	Very Low	Very Low	Very Low
Chlorophycota	*Enteromorpha clathrata*	Negligible	Very Low	Negligible	Negligible	Low	Low	Low	Low
Chlorophycota	*Monostroma obscurum*	Negligible	Low	Low	Negligible	Very Low	Low	Low	Very Low
Chlorophycota	*Ulva pertusa*	Moderate	Moderate	Moderate	Negligible	High	High	High	Low

APPENDIX B: (TABLE B2: 3/6)

Table B2: Species list with consequence ranks and risks for Environmental (ENV), Economic (ECON), Social/Cultural (S/C) and Human health (HH) based on all voyage durations (LPOC, 30d, 60d, 90d, 183d, or 365d) between 2002 and 2007.

PHYLUM	GENUS SPECIES	ENV RANK	ECON RANK	S/C RANK	HH RANK	ENV RISK	ECON RISK	S/C RISK	HUMAN HEALTH RISK
Chordata	*Botrylloides simodensis*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Chordata	*Ciona savignyi*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Chordata	*Clavelina lepadiformis*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Chordata	*Didemnum lahillei*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Chordata	*Didemnum perlucidum*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Chordata	*Didemnum vexillum*	High	Moderate	Very Low	Negligible	Extreme	High	Moderate	Low
Chordata	*Neogobius melanostomus*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Chordata	*Polyandrocarpa zorritensis*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Chordata	*Siganus luridus*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Chordata	*Siganus rivulatus*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Chordata	*Symplegma reptans*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Chordata	*Tridentiger barbatus*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Chordata	*Tridentiger bifasciatus*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Cnidaria	*Aiptasia pulchella*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Cnidaria	*Aurelia aurita*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Cnidaria	*Blackfordia virginica*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Cnidaria	*Cassiopea andromeda*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Cnidaria	*Diadumene lineata*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Cnidaria	*Gonionemus vertens*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Cnidaria	*Maeotias marginata*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Cnidaria	*Moerisia lyonsi*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Cnidaria	*Muggiaea atlantica*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Cnidaria	*Rathkea octopunctata*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Cnidaria	*Rhopilema nomadica*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Cnidaria	*Sagartia elegans*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Cnidaria	*Sagartia ornata*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Cnidaria	*Sarsia tubulosa*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low

Table B2: Species list with consequence ranks and risks for Environmental (ENV), Economic (ECON), Social/Cultural (S/C) and Human health (HH) based on all voyage durations (LPOC, 30d, 60d, 90d, 183d, or 365d) between 2002 and 2007.

PHYLUM	GENUS SPECIES	ENV RANK	ECON RANK	S/C RANK	HH RANK	ENV RISK	ECON RISK	S/C RISK	HUMAN HEALTH RISK
Cnidaria	*Thyroscyphus fruticosus*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Cnidaria	*Tiaropsis multicirrata*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Ctenophora	*Mnemiopsis leidyi*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Echinodermata	*Asterina wega*	Low	Negligible	Negligible	Negligible	Low	Very Low	Very Low	Very Low
Ectoprocta	*Buskia nitens*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Ectoprocta	*Membranipora tenuis*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Ectoprocta	*Pectinatella magnifica*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Ectoprocta	*Sundanella sibogae*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Entoprocta	*Loxosomatoides laevis*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Heterokontophyta	*Chattonella antiqua*	Moderate	High	Negligible	Negligible	Moderate	Moderate	Very Low	Very Low
Heterokontophyta	*Fucus evanescens*	Moderate	Negligible	Negligible	Negligible	Moderate	Low	Low	Low
Heterokontophyta	*Pseudocattonella farcimen*	Moderate	High	Negligible	Negligible	Moderate	Moderate	Very Low	Very Low
Heterokontophyta	*Sargassum muticum*	High	High	Moderate	Negligible	Extreme	Extreme	High	Low
Mollusca	*Anadara demiri*	Low	Moderate	Negligible	Negligible	Moderate	Moderate	Low	Low
Mollusca	*Anomia nobilis*	Moderate	Negligible	Negligible	Negligible	High	Low	Low	Low
Mollusca	*Brachidontes variabilis*	High	High	Negligible	Negligible	High	High	Low	Low
Mollusca	*Cerithium scabridum*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Mollusca	*Corbicula fluminea*	Low	High	Negligible	Negligible	Moderate	High	Low	Low
Mollusca	*Crassostrea ariakensis*	Low	Low	Negligible	High	Moderate	Moderate	Low	High
Mollusca	*Crassostrea virginica*	Moderate	High	Negligible	Moderate	High	High	Low	High
Mollusca	*Crepidula fornicata*	High	High	Negligible	Negligible	High	High	Low	Low
Mollusca	*Crepidula lingulata*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Mollusca	*Crucibulum spinosum*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Mollusca	*Dreissena bugensis*	Moderate	High	Low	Very Low	Moderate	High	Moderate	Low
Mollusca	*Dreissena polymorpha*	High	High	Moderate	Very Low	High	High	Moderate	Low
Mollusca	*Ensis directus*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Mollusca	*Geukensia demissa*	Extreme	Negligible	Negligible	Negligible	Moderate	Very Low	Very Low	Very Low

Table B2: Species list with consequence ranks and risks for Environmental (ENV), Economic (ECON), Social/Cultural (S/C) and Human health (HH) based on all voyage durations (LPOC, 30d, 60d, 90d, 183d, or 365d) between 2002 and 2007.

PHYLUM	GENUS SPECIES	ENV RANK	ECON RANK	S/C RANK	HH RANK	ENV RISK	ECON RISK	S/C RISK	HUMAN HEALTH RISK
Mollusca	*Limnoperna fortunei*	Moderate	Moderate	Negligible	Moderate	High	High	Low	High
Mollusca	*Lithoglyphus naticoides*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Mollusca	*Mactra nitida*	Negligible	Negligible	Negligible	Low	Very Low	Very Low	Very Low	Low
Mollusca	*Melibe viridis*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Mollusca	*Meretrix lusoria*	Negligible	Negligible	Negligible	Low	Very Low	Very Low	Very Low	Low
Mollusca	*Mya arenaria*	Very Low	Very Low	Negligible	High	Low	Low	Very Low	Moderate
Mollusca	*Mytella charruana*	Moderate	High	Negligible	Negligible	Moderate	Moderate	Very Low	Very Low
Mollusca	*Mytilopsis leucophaeta*	Moderate	High	Negligible	Negligible	High	Extreme	Low	Low
Mollusca	*Mytilopsis sallei*	Moderate	High	Low	Negligible	High	Extreme	Moderate	Low
Mollusca	*Perna perna*	High	Low	Moderate	Extreme	High	Moderate	High	Extreme
Mollusca	*Perna viridis*	Moderate	Low	Moderate	Extreme	High	Moderate	High	Extreme
Mollusca	*Corbula (Potamocorbula) amurensis*	Low	Very Low	Very Low	Negligible	Moderate	Low	Low	Low
Mollusca	*Pyrgophorus coronatus*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Mollusca	*Rapana venosa (thomasiana)*	High	Moderate	Negligible	Negligible	High	Moderate	Very Low	Very Low
Mollusca	*Sabia conica*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Mollusca	*Siphonaria pectinata*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Mollusca	*Tarebia granifera*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Mollusca	*Tenellia adspersa*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Mollusca	*Tritonia plebeia*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Mollusca	*Viviparus georgianus*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Nematoda	*Anguillicola crassus*	Moderate	High	Negligible	Negligible	Moderate	Moderate	Very Low	Very Low
Nematoda	*Camallanus cotti*	Negligible	Low	Negligible	Negligible	Very Low	Low	Very Low	Very Low
Porifera	*Cliona thoosina*	High	High	Moderate	Negligible	High	High	Moderate	Low
Porifera	*Eunapius carteri*	Very Low	Negligible	Negligible	Negligible	Low	Low	Low	Low
Porifera	*Gelliodes fibrosa*	Moderate	Negligible	Negligible	Negligible	Moderate	Low	Low	Low
Protozoa	*Bonamia ostreae*	Negligible	High	Negligible	Negligible	Low	High	Low	Low
Pyrrophycophyta	*Alexandrium monilatum*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Pyrrophycophyta	*Dinophysis norvegica*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low

APPENDIX B: (TABLE B2: 6/6)

Table B2: Species list with consequence ranks and risks for Environmental (ENV), Economic (ECON), Social/Cultural (S/C) and Human health (HH) based on all voyage durations (LPOC, 30d, 60d, 90d, 183d, or 365d) between 2002 and 2007.

PHYLUM	GENUS SPECIES	ENV RANK	ECON RANK	S/C RANK	HH RANK	ENV RISK	ECON RISK	S/C RISK	HUMAN HEALTH RISK
Pyrrophycophyta	*Pfiesteria piscicida*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Rhodophycota	*Acrochaetium balticum*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Rhodophycota	*Aglaothamnion halliae*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Antithamnion densum*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Antithamnion nipponicum*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Antithamnionella elegans*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Antithamnionella sublittoralis*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Asparagopsis armata*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Bonnemaisonia hamifera*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Caulacanthus ustulatus*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Chondrus giganteus*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Chrysymenia wrightii*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Dasya sessilis*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Rhodophycota	*Gracilaria tikvahiae*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Rhodophycota	*Gracilaria vermiculophylla*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Grateloupia doryphora*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Heterosiphonia japonica*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Hypnea musciformis*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Kappaphycus alvarezii*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Kappaphycus striatum*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Lithophyllum yessoense*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Lophocladia lallemandii*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Rhodophycota	*Mastocarpus stellatus*	Negligible	Negligible	Negligible	Negligible	Very Low	Very Low	Very Low	Very Low
Rhodophycota	*Polysiphonia breviarticulata*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Polysiphonia harveyi*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Polysiphonia morrowii*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Polysiphonia nigrescens*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low
Rhodophycota	*Womersleyella setacea*	Negligible	Negligible	Negligible	Negligible	Low	Low	Low	Low

APPENDIX C

Figure C1: Number and percentage of vessel visits to Australia in 2002 that traded with specific bioregions over voyages of 30, 60, 90, 183 and 365 days.

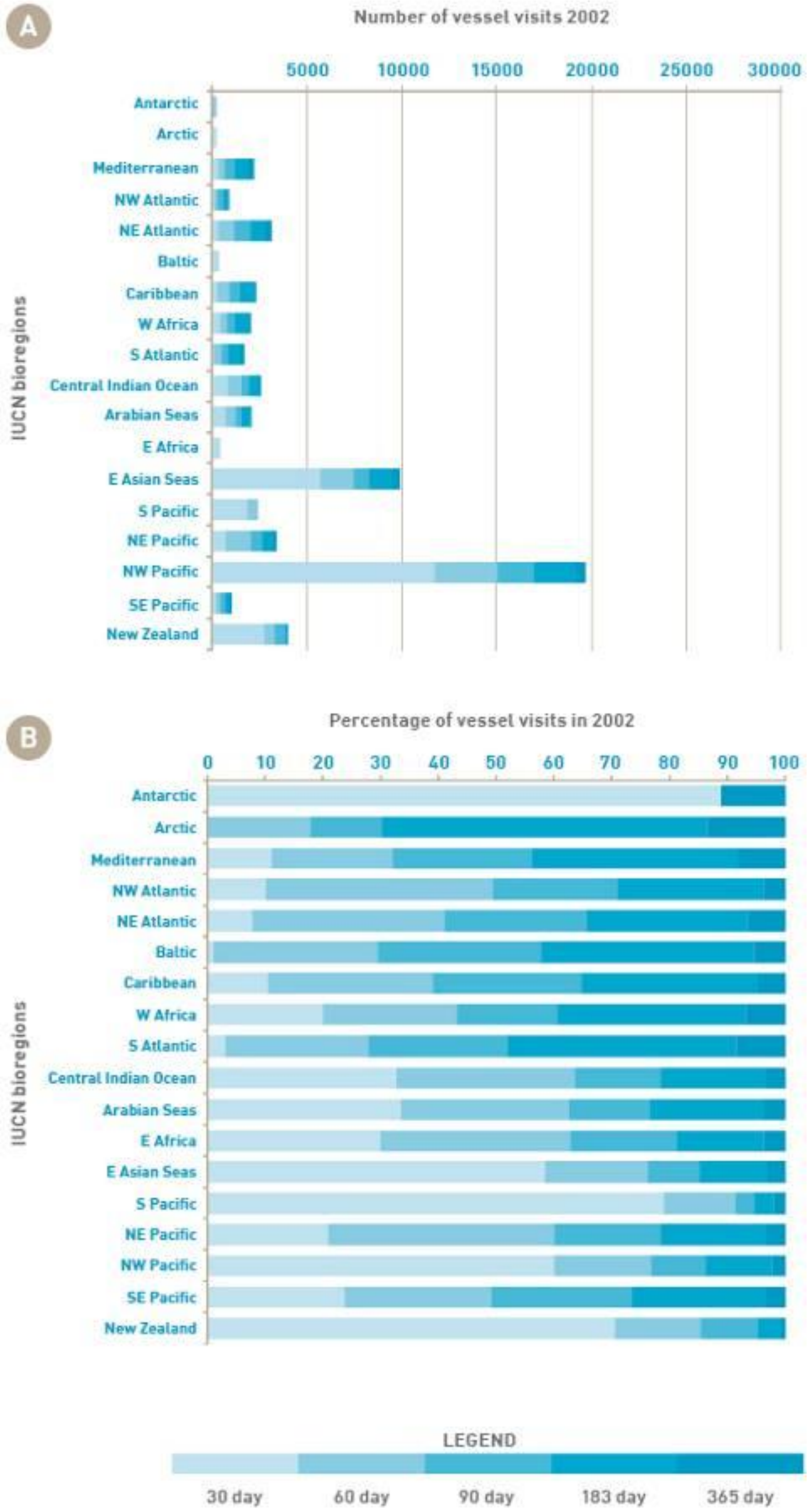
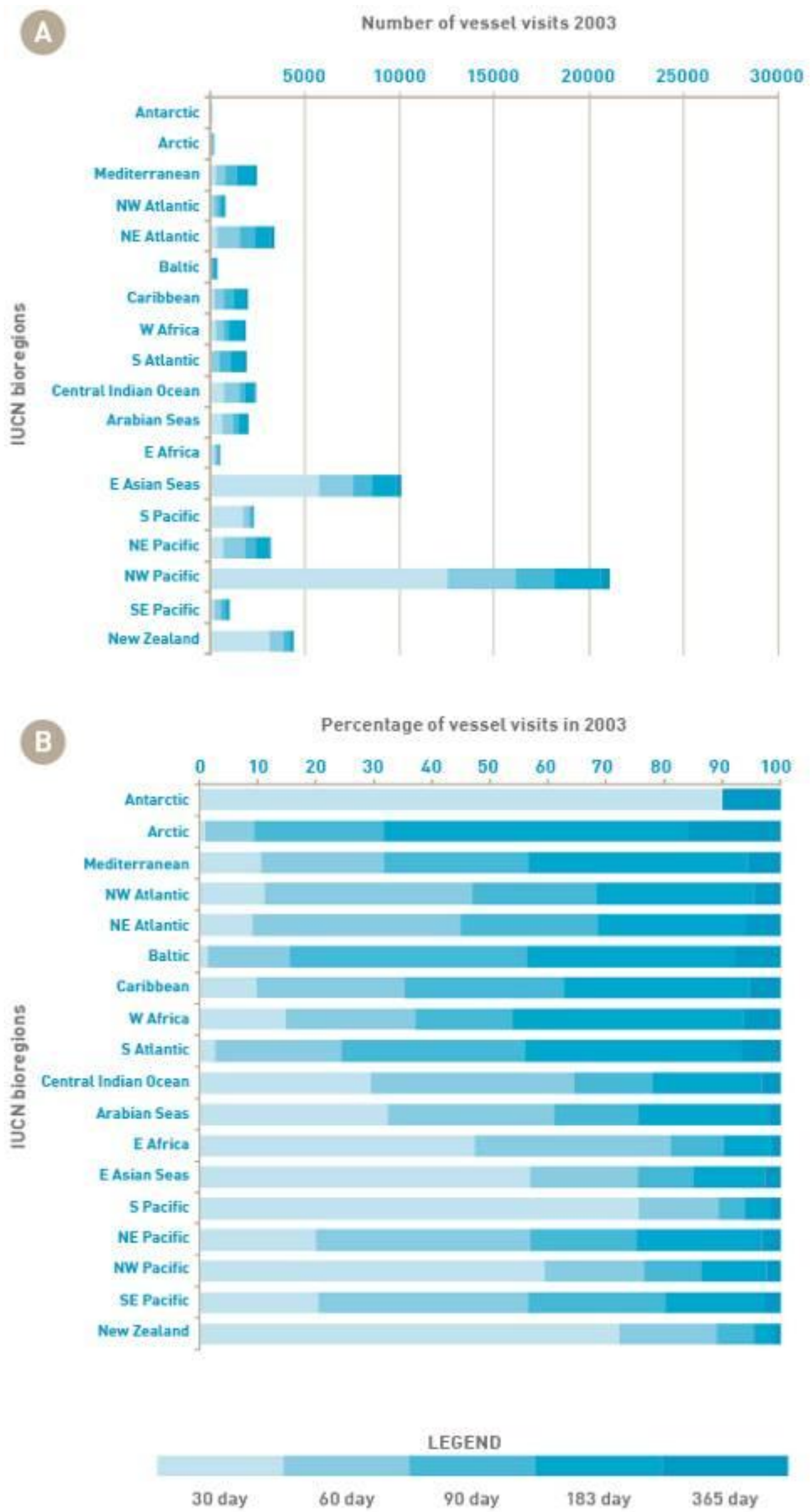


Figure C2: Number and percentage of vessel visits to Australia in 2003 that traded with specific bioregions over voyages of 30, 60, 90, 183 and 365 days.



APPENDIX C

Figure C3: Number and percentage of vessel visits to Australia in 2004 that traded with specific bioregions over voyages of 30, 60, 90, 183 and 365 days.

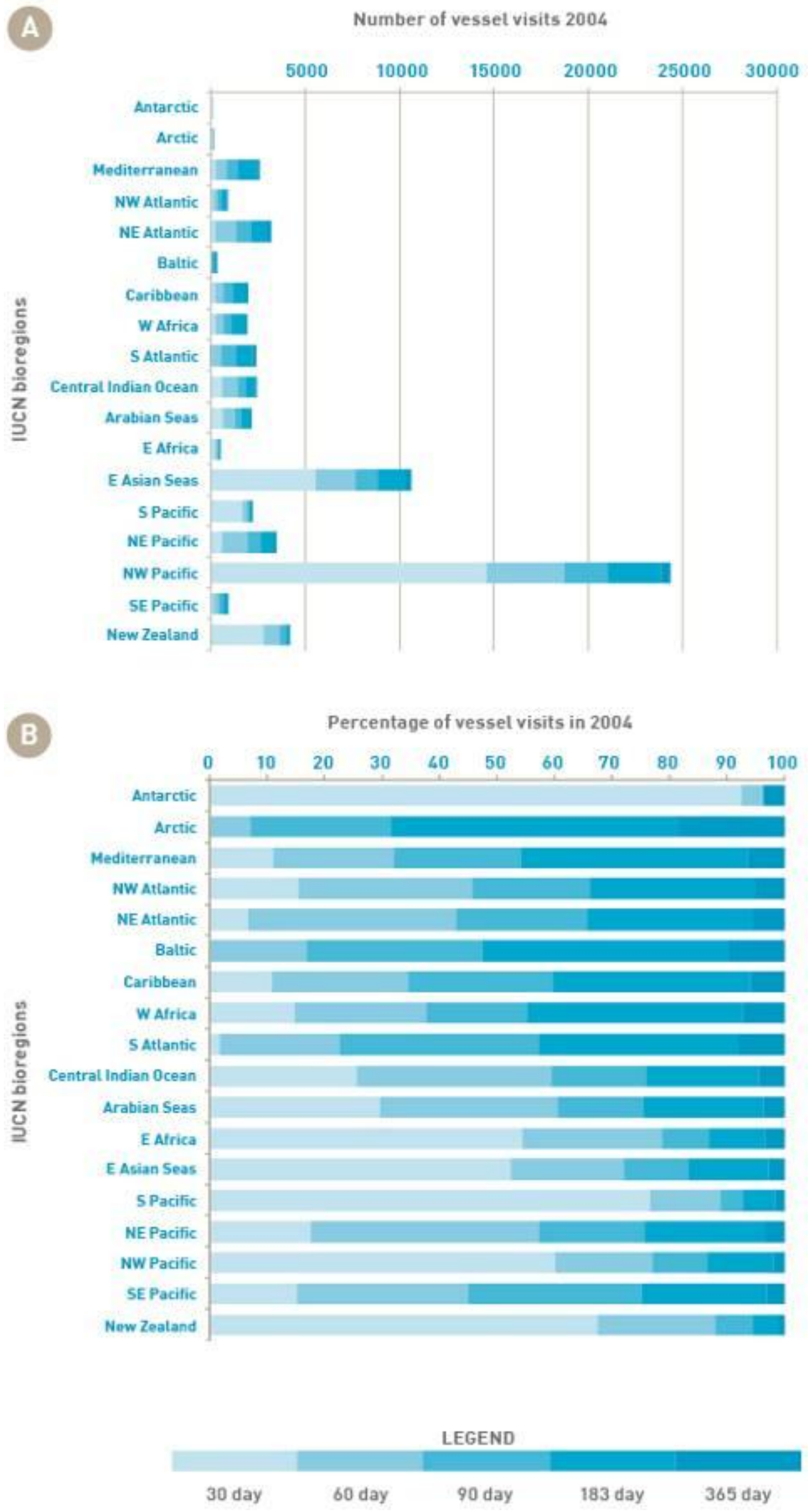


Figure C4: Number and percentage of vessel visits to Australia in 2005 that traded with specific bioregions over voyages of 30, 60, 90, 183 and 365 days.

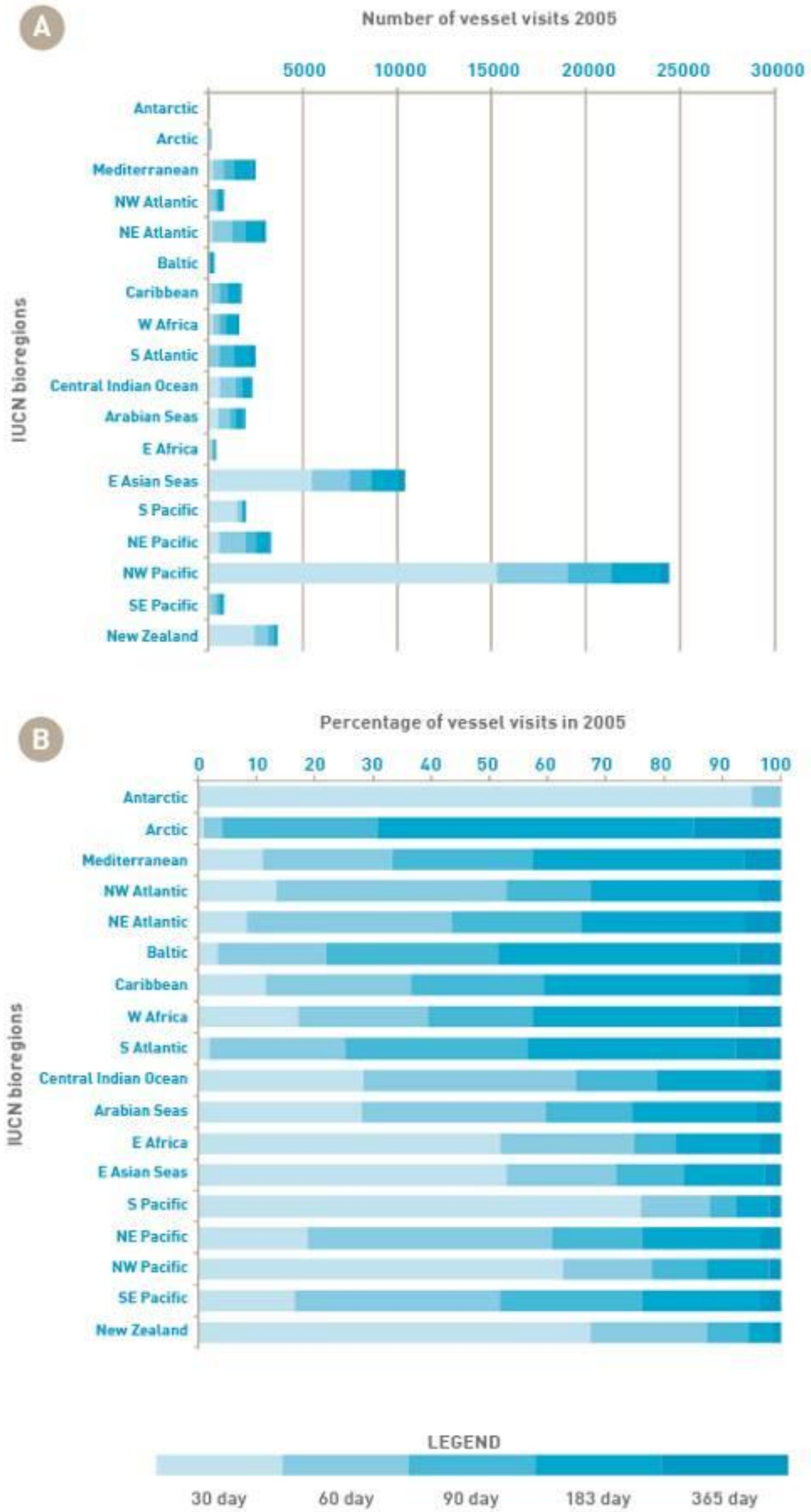


Figure C5: Number and percentage of vessel visits to Australia in 2006 that traded with specific bioregions over voyages of 30, 60, 90, 183 and 365 days.

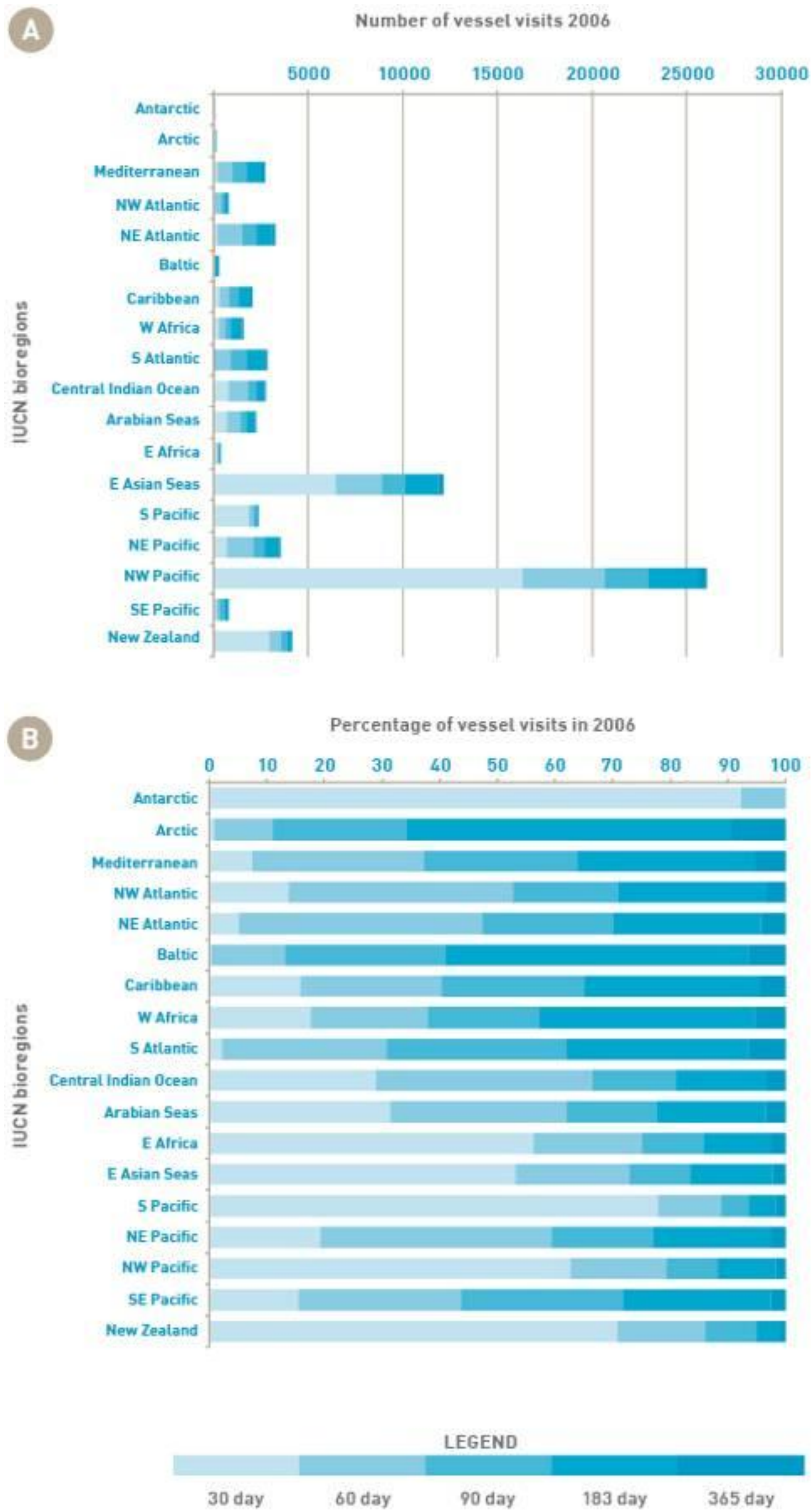
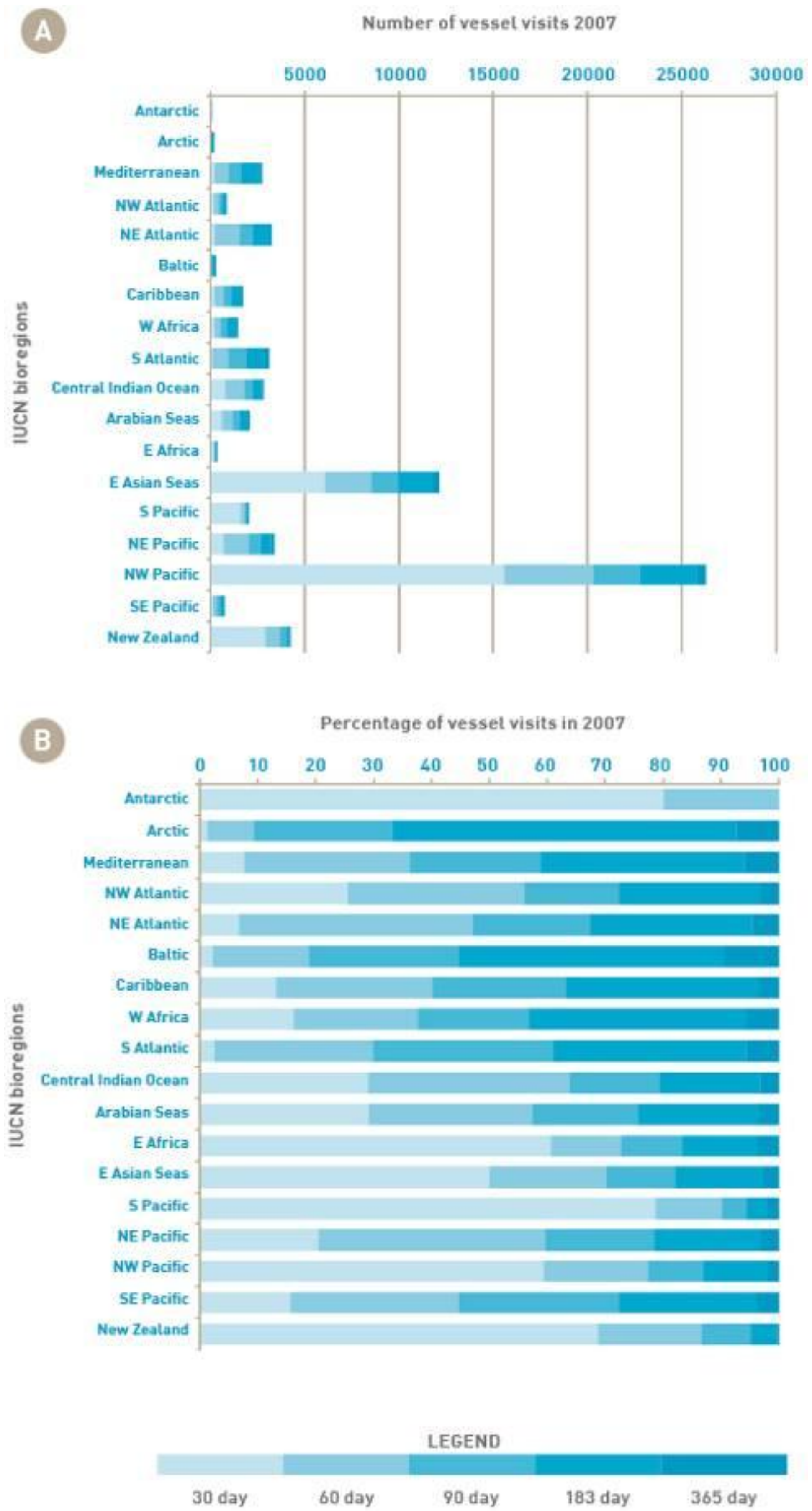
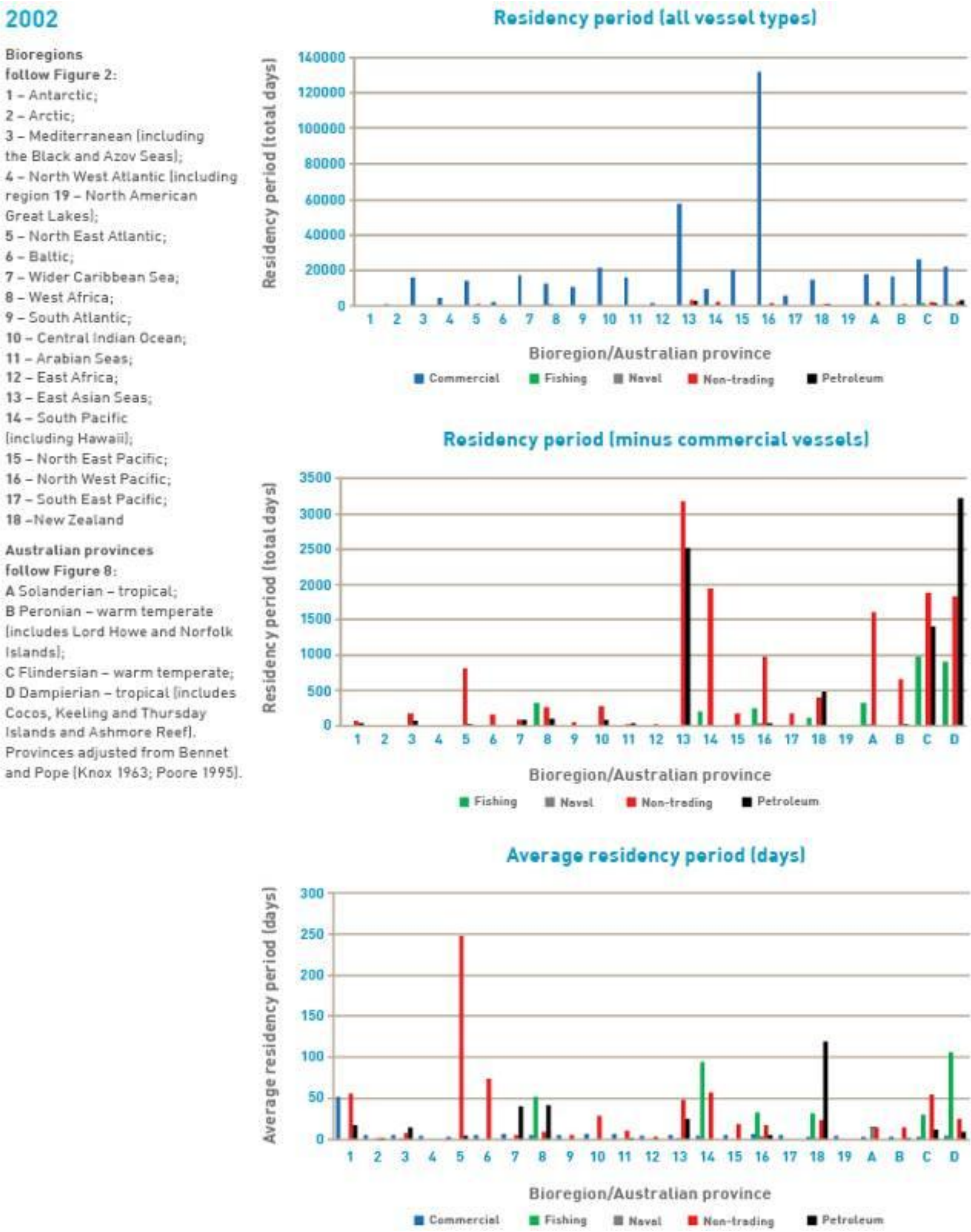


Figure C6: Number and percentage of vessel visits to Australia in 2007 that traded with specific bioregions over voyages of 30, 60, 90, 183 and 365 days.



APPENDIX D

Graphs showing total and average residency periods of vessels (by category) from 2002 to 2007 across IUCN bioregions and Australian Provinces (Lloyds MIU dataset).



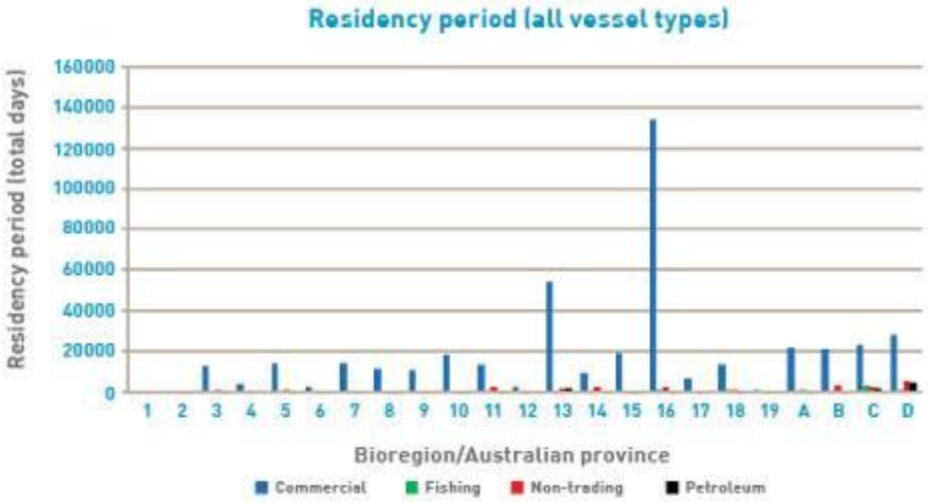
APPENDIX D

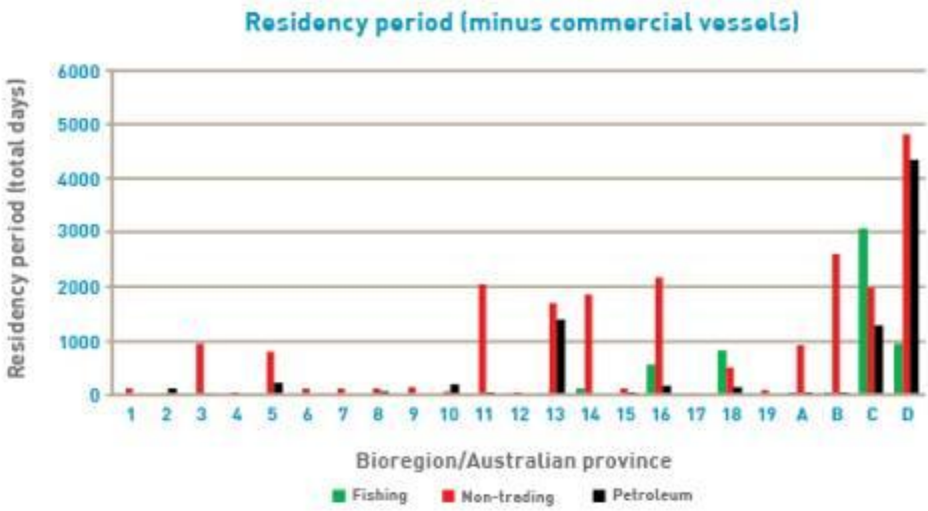
Graphs showing total and average residency periods of vessels (by category) from 2002 to 2007 across IUCN bioregions and Australian Provinces (Lloyds MIU dataset).

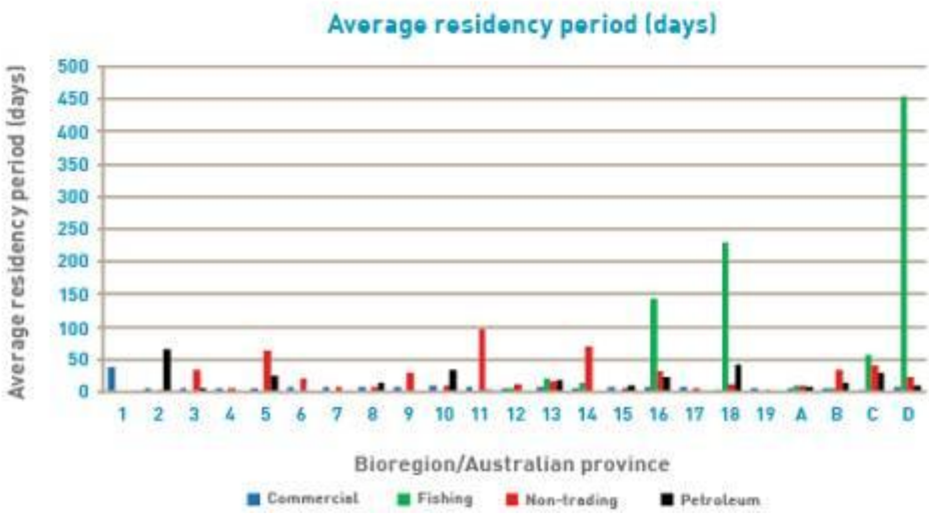
2003

Bioregions follow Figure 2:
1 – Antarctic;
2 – Arctic;
3 – Mediterranean (including the Black and Azov Seas);
4 – North West Atlantic (including region 19 – North American Great Lakes);
5 – North East Atlantic;
6 – Baltic;
7 – Wider Caribbean Sea;
8 – West Africa;
9 – South Atlantic;
10 – Central Indian Ocean;
11 – Arabian Seas;
12 – East Africa;
13 – East Asian Seas;
14 – South Pacific (including Hawaii);
15 – North East Pacific;
16 – North West Pacific;
17 – South East Pacific;
18 –New Zealand

Australian provinces follow Figure 8:
A Solanderian – tropical;
B Peronian – warm temperate (includes Lord Howe and Norfolk Islands);
C Flindersian – warm temperate;
D Dampierian – tropical (includes Cocos, Keeling and Thursday Islands and Ashmore Reef).
Provinces adjusted from Bennet and Pope (Knox 1963; Poore 1995).







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2004

Bioregions follow Figure 2:
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6 – Baltic;
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8 – West Africa;
9 – South Atlantic;
10 – Central Indian Ocean;
11 – Arabian Seas;
12 – East Africa;
13 – East Asian Seas;
14 – South Pacific (including Hawaii);
15 – North East Pacific;
16 – North West Pacific;
17 – South East Pacific;
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Australian provinces follow Figure 8:
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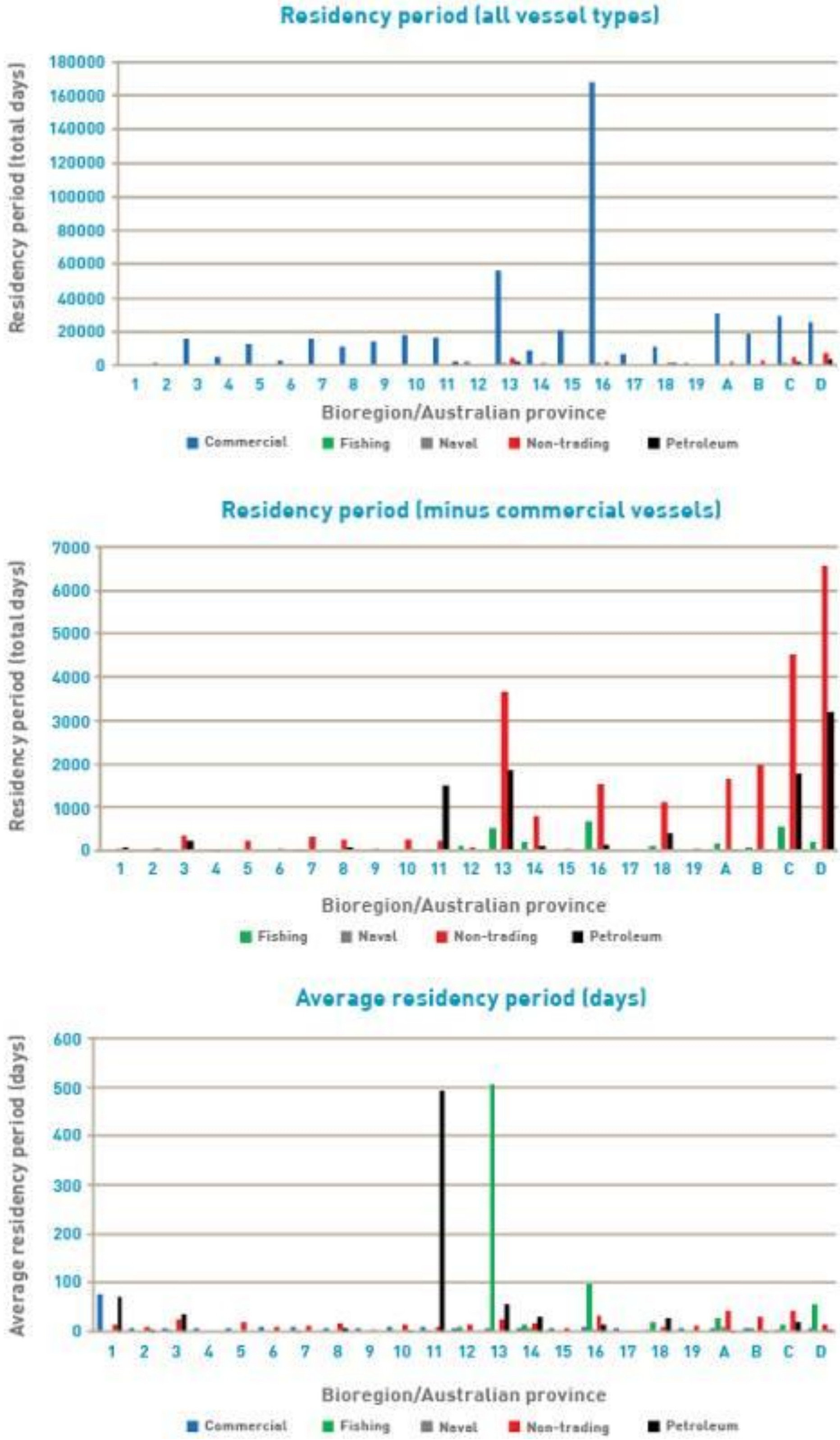
Provinces adjusted from Bennet and Pope (Knox 1963; Poore 1995).



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Graphs showing total and average residency periods of vessels (by category) from 2002 to 2007 across IUCN bioregions and Australian Provinces (Lloyds MIU dataset).

2005

Bioregions follow Figure 2:
1 – Antarctic;
2 – Arctic;
3 – Mediterranean (including the Black and Azov Seas);
4 – North West Atlantic (including region 19 – North American Great Lakes);
5 – North East Atlantic;
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7 – Wider Caribbean Sea;
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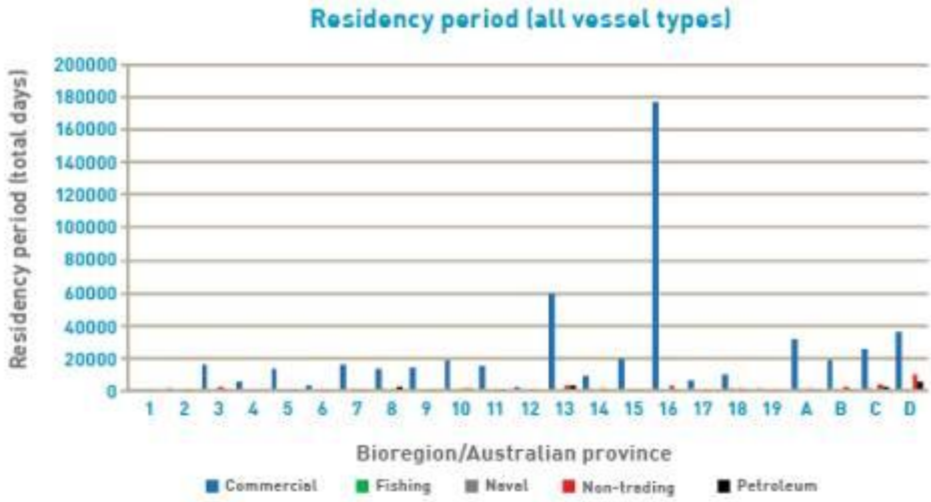
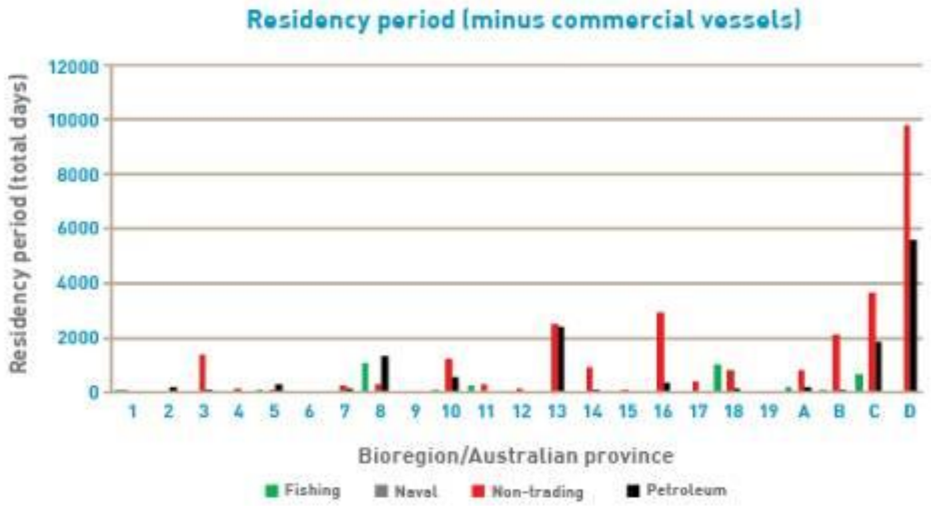
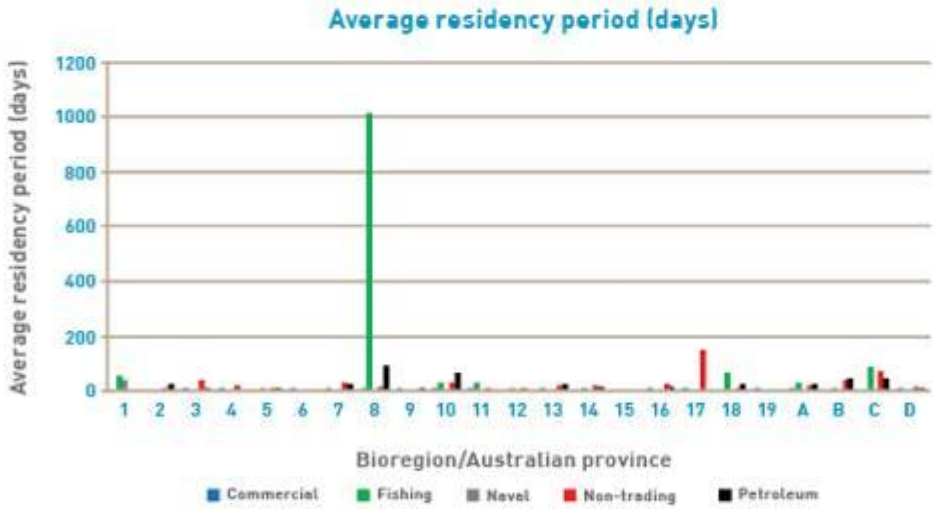
9 – South Atlantic;
10 – Central Indian Ocean;
11 – Arabian Seas;
12 – East Africa;
13 – East Asian Seas;
14 – South Pacific (including Hawaii);
15 – North East Pacific;
16 – North West Pacific;
17 – South East Pacific;
18 –New Zealand

Australian provinces follow Figure 8:
A Solanderian – tropical;
B Peronian – warm temperate (includes Lord Howe and Norfolk Islands);
C Flindersian – warm temperate;
D Dampierian – tropical (includes Cocos, Keeling and Thursday Islands and Ashmore Reef).
Provinces adjusted from Bennet and Pope (Knox 1963; Poore 1995).







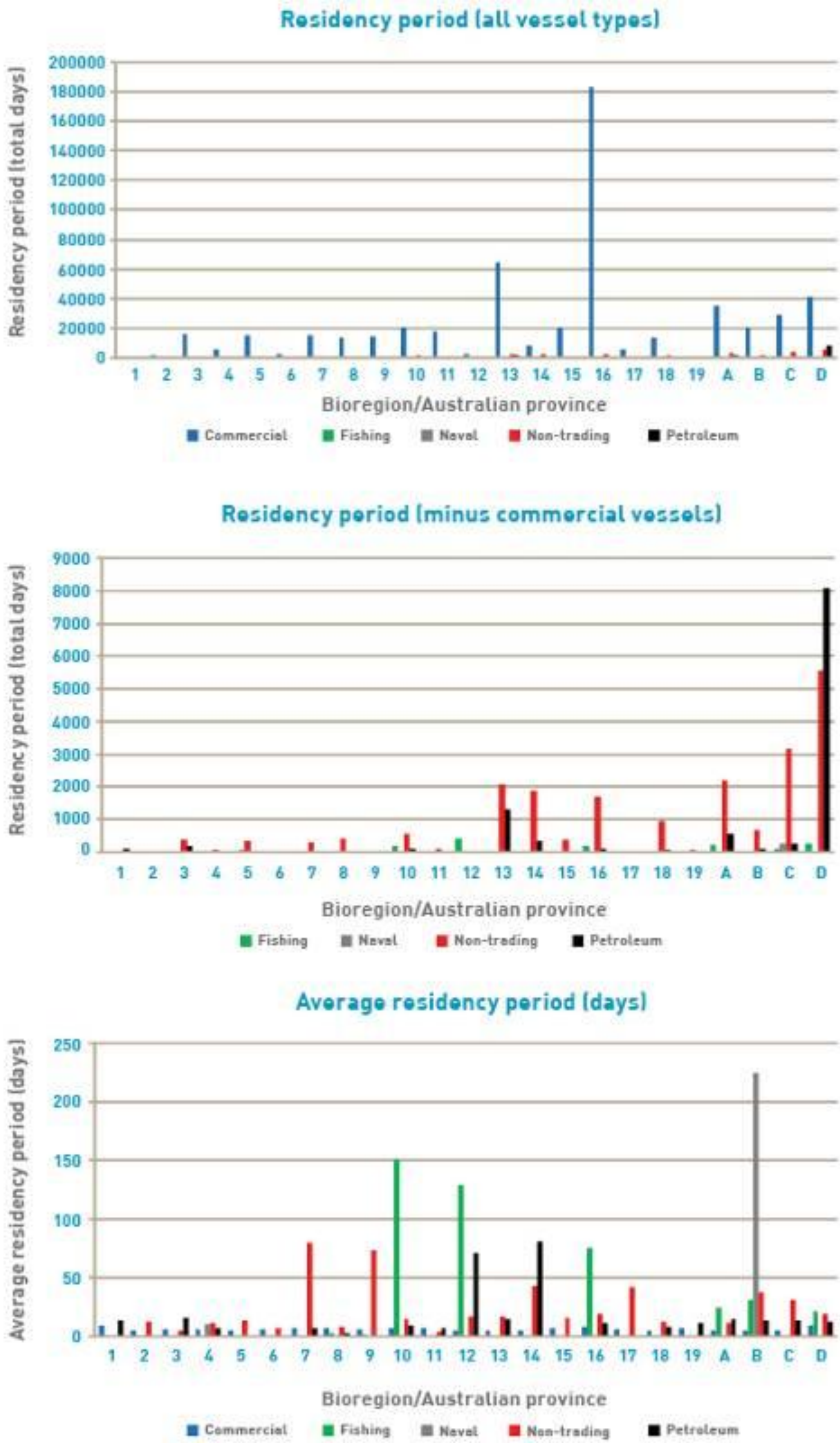
APPENDIX D

Graphs showing total and average residency periods of vessels (by category) from 2002 to 2007 across IUCN bioregions and Australian Provinces (Lloyds MIU dataset).

2006

Bioregions follow Figure 2:
1 – Antarctic;
2 – Arctic;
3 – Mediterranean (including the Black and Azov Seas);
4 – North West Atlantic (including region 19 – North American Great Lakes);
5 – North East Atlantic;
6 – Baltic;
7 – Wider Caribbean Sea;
8 – West Africa;
9 – South Atlantic;
10 – Central Indian Ocean;
11 – Arabian Seas;
12 – East Africa;
13 – East Asian Seas;
14 – South Pacific (including Hawaii);
15 – North East Pacific;
16 – North West Pacific;
17 – South East Pacific;
18 –New Zealand

Australian provinces follow Figure 8:
A Solanderian – tropical;
B Peronian – warm temperate (includes Lord Howe and Norfolk Islands);
C Flindersian – warm temperate;
D Dampierian – tropical (includes Cocos, Keeling and Thursday Islands and Ashmore Reef).
Provinces adjusted from Bennet and Pope (Knox 1963; Poore 1995).



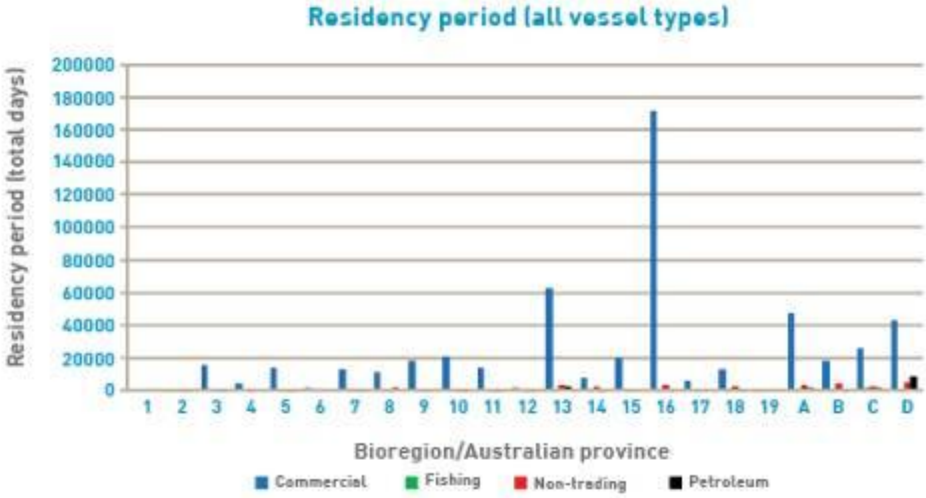
APPENDIX D

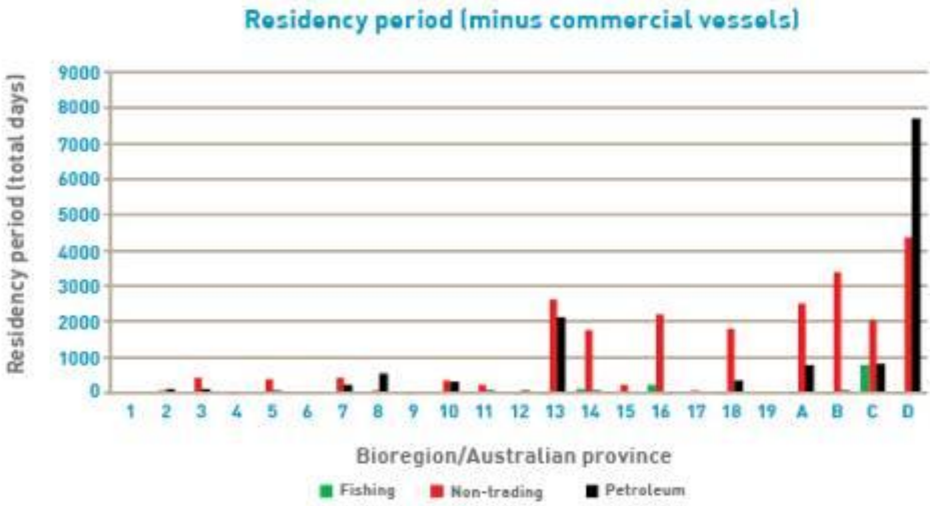
Graphs showing total and average residency periods of vessels (by category) from 2002 to 2007 across IUCN bioregions and Australian Provinces (Lloyds MIU dataset).

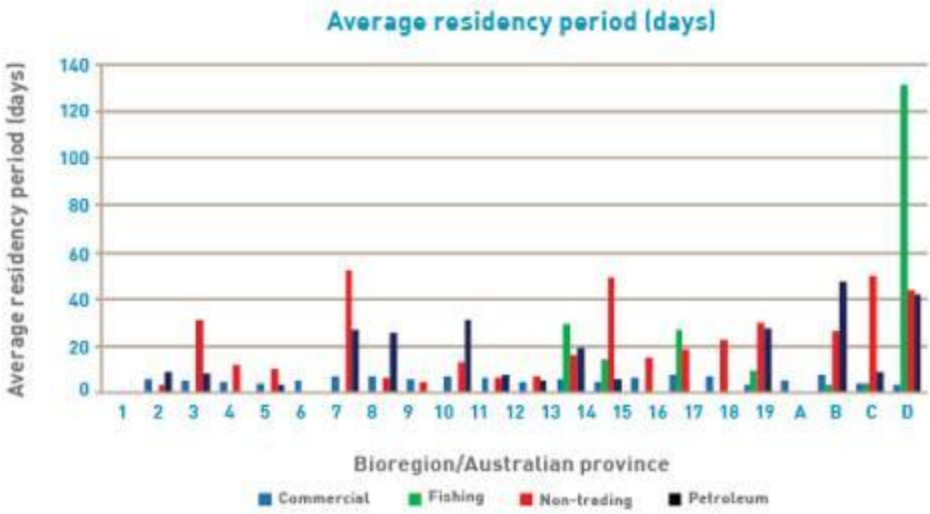
2007

Bioregions follow Figure 2:
1 – Antarctic;
2 – Arctic;
3 – Mediterranean (including the Black and Azov Seas);
4 – North West Atlantic (including region 19 – North American Great Lakes);
5 – North East Atlantic;
6 – Baltic;
7 – Wider Caribbean Sea;
8 – West Africa;
9 – South Atlantic;
10 – Central Indian Ocean;
11 – Arabian Seas;
12 – East Africa;
13 – East Asian Seas;
14 – South Pacific (including Hawaii);
15 – North East Pacific;
16 – North West Pacific;
17 – South East Pacific;
18 –New Zealand

Australian provinces follow Figure 8:
A Solanderian – tropical;
B Peronian – warm temperate (includes Lord Howe and Norfolk Islands);
C Flindersian – warm temperate;
D Dampierian – tropical (includes Cocos, Keeling and Thursday Islands and Ashmore Reef).
Provinces adjusted from Bennet and Pope (Knox 1963; Poore 1995).







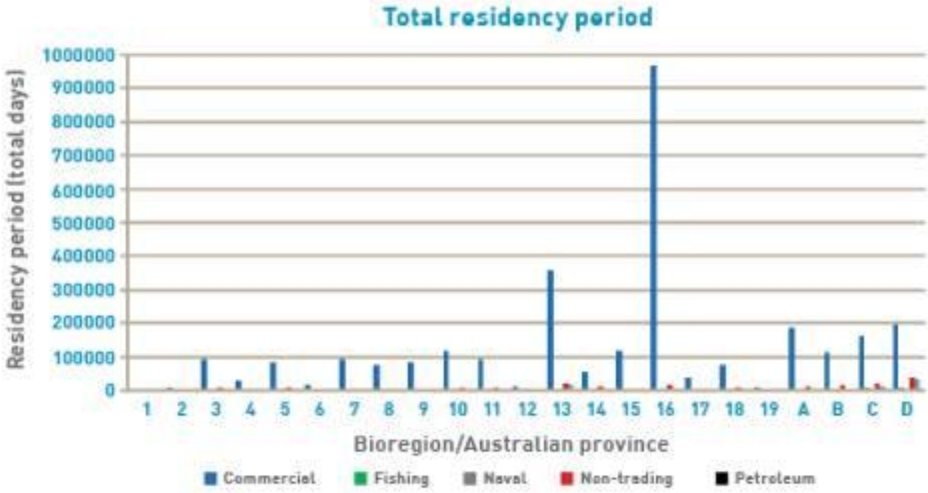
APPENDIX D

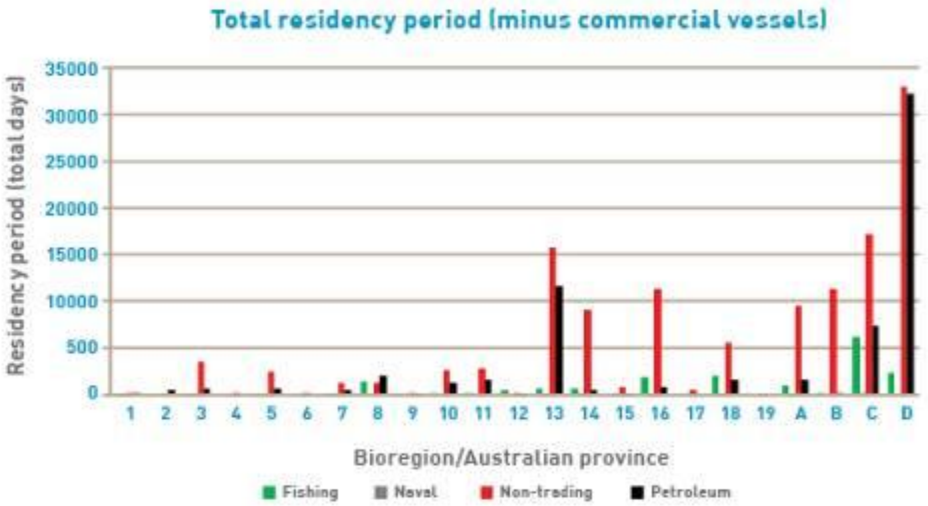
Graphs showing total and average residency periods of vessels (by category) from 2002 to 2007 across IUCN bioregions and Australian Provinces (Lloyds MIU dataset).

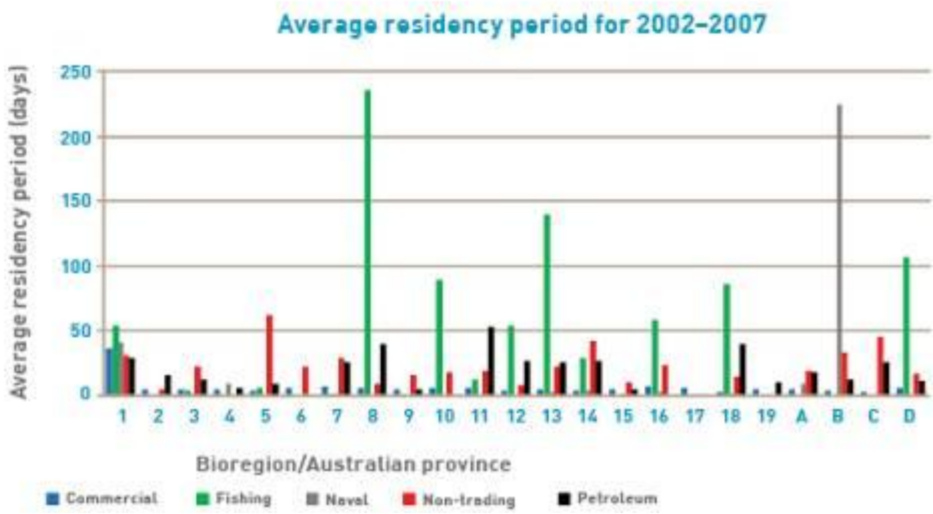
Overall
(2002 to 2007 combined)

Bioregions follow Figure 2:
1 – Antarctic;
2 – Arctic;
3 – Mediterranean (including the Black and Azov Seas);
4 – North West Atlantic (including region 19 – North American Great Lakes);
5 – North East Atlantic;
6 – Baltic;
7 – Wider Caribbean Sea;
8 – West Africa;
9 – South Atlantic;
10 – Central Indian Ocean;
11 – Arabian Seas;
12 – East Africa;
13 – East Asian Seas;
14 – South Pacific (including Hawaii);
15 – North East Pacific;
16 – North West Pacific;
17 – South East Pacific;
18 –New Zealand

Australian provinces follow Figure 8:
A Solanderian – tropical;
B Peronian – warm temperate (includes Lord Howe and Norfolk Islands);
C Flindersian – warm temperate;
D Dampierian – tropical (includes Cocos, Keeling and Thursday Islands and Ashmore Reef).
Provinces adjusted from Bennet and Pope (Knox 1963; Poore 1995).







APPENDIX E

Table E1: 2002 residency periods in port for commercial, petroleum, fishing, naval, and non-trading vessels.
Note: recreational vessels >25 m are included in non-trading; recreational vessels <25 m and IFFVs are not included (Lloyds MIU dataset).

DAFF Vessel Category	Bioregion/ Province	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	A	B	C	D
COMMERCIAL	Total days	205	580	15728	4257	14133	2205	16766	12260	10200	21280	16089	1577	57468	9527	19925	131414	5903	14691	424	17469	16509	26289	21840
	Average	53	7	6	6	4	6	7	6	6	8	8	6	7	5	6	7	6	4	6	3	4	4	6
	sd	0	5	9	8	5	4	8	9	10	12	12	8	17	19	8	18	10	21	5	4	6	10	9
	se	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	n	4	85	2675	770	3236	353	2411	2171	1741	2656	2176	296	9004	2025	3429	18570	969	3768	82	5343	4253	7526	3980
PETROLEUM	Total days	37	3	59	0	15	0	81	87	0	81	27	0	2511	0	0	29	0	477	0	0	19	1405	3208
	Average	19	3	15	0	5	0	41	43	0	0	3	0	26	0	0	6	0	119	0	0	3	13	10
	sd	2	0	19	0	6	0	0	0	0	0	0	0	38	0	0	4	0	41	0	0	2	41	33
	se	2	0	9	0	4	0	0	0	0	0	0	0	4	0	0	2	0	21	0	0	1	4	2
FISHING	Total days	0	0	0	0	0	0	0	315	0	0	0	0	1	196	0	241	0	101	0	321	0	982	901
	Average	0	0	0	0	0	0	0	53	0	0	0	0	1	95	0	33	0	32	0	0	0	30	107
	sd	0	0	0	0	0	0	0	65	0	0	0	0	0	0	0	25	0	0	0	0	0	45	0
	se	0	0	0	0	0	0	0	27	0	0	0	0	0	0	0	10	0	0	0	0	0	6	0
	n	0	0	0	0	0	0	0	6	0	0	0	0	1	4	0	6	0	5	0	2	2	51	11
NAVAL	Total days	0	0	2	0	0	0	0	0	0	0	0	0	3	0	0	26	0	2	0	16	0	0	0
	Average	0	0	2	0	0	0	0	0	0	0	0	0	3	0	0	3	0	2	0	16	0	0	0
	sd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	se	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	n	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	8	0	1	0	1	0	0	0
NON-TRADING	Total days	56	2	172	0	801	149	71	255	41	281	24	10	3165	1940	172	972	165	391	0	1592	657	1867	1820
	Average	56	2	10	0	248	75	6	10	7	30	12	4	49	58	19	18	0	25	0	15	15	56	26
	sd	0	0	16	0	0	0	4	10	5	35	0	0	110	115	24	40	0	35	0	49	23	128	59
	se	0	0	4	0	0	0	1	2	2	12	0	0	11	13	8	5	0	8	0	6	3	17	7
	n	1	1	18	0	6	2	12	24	6	9	2	3	93	75	9	53	5	18	0	71	49	55	63
	n	2	1	5	0	3	0	2	3	0	7	7	0	102	0	0	5	0	4	0	0	7	96	290

Bioregions follow Figure 2: 1 – Antarctica; 2 – Arctic; 3 – Mediterranean (including the Black and Azov Seas); 4 – North West Atlantic (including region 19 – North American Great Lakes); 5 – North East Atlantic; 6 – Baltic; 7 – Wider Caribbean Sea; 8 – West Africa; 9 – South Atlantic; 10 – Central Indian Ocean; 11 – Arabian Seas; 12 – East Africa; 13 – East Asian Seas; 14 – South Pacific (including Hawaii); 15 – North East Pacific; 16 – North West Pacific; 17 – South East Pacific; 18 –New Zealand

Australian Provinces follow Figure 8: A Solanderian – Tropical; B Peronian – Warm Temperate (includes Lord Howe and Norfolk Islands); C Flindersian – Warm Temperate; D Dampierian – Tropical (includes Cocos, Keeling and Thursday Islands and Ashmore Reef). Provinces adjusted from Bennet and Pope (Knox 1963; Poore 1995)

Table E2: 2003 residency periods in port for commercial, petroleum, fishing and non-trading vessels.
Note: recreational vessels >25 m are included in non-trading; no naval vessels were recorded, recreational vessels <25 m and IFFVs are not included (Lloyds MIU dataset).

DAFF Vessel Category	Bioregion/ Province	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	A	B	C	D
COMMERCIAL	Total days	75	362	12306	3328	13845	2293	13844	11386	10629	18292	13485	1822	53835	9051	18890	133738	6567	13003	440	21871	20556	23053	28064
	Average	38	5	5	4	4	7	7	6	6	8	7	4	6	5	6	7	6	3	5	4	5	3	7
	sd	0	5	6	5	4	8	8	10	7	9	17	8	14	10	7	13	10	8	4	6	15	6	20
	se	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	n	2	98	2717	839	3475	360	2076	1891	1922	2540	2015	467	9459	2044	3343	19134	1109	4250	96	5152	4098	7644	4072
PETROLEUM	Total days	0	130	16	0	221	0	0	61	0	206	30	0	1399	0	47	178	0	150	0	29	52	1282	4347
	Average	0	65	4	0	24	0	0	12	0	32	3	0	17	0	8	21	0	40	0	8	14	29	9
	sd	0	91	0	0	29	0	0	10	0	0	0	0	26	0	11	27	0	0	0	0	0	45	36
	se	0	64	0	0	9	0	0	5	0	0	0	0	3	0	4	8	0	0	0	0	0	6	2
	n	0	2	4	0	11	0	0	5	0	7	10	0	78	0	6	12	0	3	0	3	3	50	440
FISHING	Total days	0	0	0	0	0	0	0	0	0	0	0	10	20	122	0	566	0	811	0	34	25	3066	943
	Average	0	0	0	0	0	0	0	0	0	0	0	3	20	12	0	142	0	229	0	9	4	56	452
	sd	0	0	0	0	0	0	0	0	0	0	0	2	0	17	0	130	0	0	0	2	1	156	0
	se	0	0	0	0	0	0	0	0	0	0	0	1	0	6	0	65	0	0	0	1	1	22	0
	n	0	0	0	0	0	0	0	0	0	0	0	3	1	9	0	4	0	22	0	5	6	51	8
NON-TRADING	Total days	106	7	936	37	777	103	114	117	144	68	2041	40	1679	1856	100	2152	4	491	76	900	2612	1980	4803
	Average	0	2	33	5	63	20	7	6	28	8	94	11	16	70	4	31	4	10	2	9	32	38	21
	sd	0	0	92	0	104	13	8	0	15	11	299	0	28	181	0	55	0	18	3	11	124	89	84
	se	0	0	18	0	11	6	2	0	5	4	75	0	3	30	0	6	0	3	1	1	13	12	5
	n	3	4	25	9	83	5	18	9	9	9	16	3	123	36	18	76	1	47	32	82	86	53	294

Bioregions follow Figure 2: 1 – Antarctica; 2 – Arctic; 3 – Mediterranean (including the Black and Azov Seas); 4 – North West Atlantic (including region 19 – North American Great Lakes); 5 – North East Atlantic; 6 – Baltic; 7 – Wider Caribbean Sea; 8 – West Africa; 9 – South Atlantic; 10 – Central Indian Ocean; 11 – Arabian Seas; 12 – East Africa; 13 – East Asian Seas; 14 – South Pacific (including Hawaii); 15 – North East Pacific; 16 – North West Pacific; 17 – South East Pacific; 18 –New Zealand

Australian Provinces follow Figure 8: A Solanderian – Tropical; B Peronian – Warm Temperate (includes Lord Howe and Norfolk Islands); C Flindersian – Warm Temperate; D Dampierian – Tropical (includes Cocos, Keeling and Thursday Islands and Ashmore Reef). Provinces adjusted from Bennet and Pope (Knox 1963; Poore 1995)

APPENDIX E

Table E3: 2004 residency periods in port for commercial, petroleum, fishing, naval, and non-trading vessels.
Note: recreational vessels >25 m are included in non-trading; recreational vessels <25 m and IFFVs are not included (Lloyds MIU dataset).

DAFF Vessel Category	Bioregion/ Province	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	A	B	C	D
COMMERCIAL	Total days	151	228	5243	1559	4212	785	5127	3710	4642	5771	5390	592	18614	2898	7028	55988	1997	3633	207	10205	6232	9814	8398
	Average	76	6	5	5	4	7	7	6	6	7	7	4	6	5	6	8	6	3	6	6	4	4	6
	sd	49	4	6	5	4	6	9	8	7	8	10	6	10	9	7	17	8	4	7	17	8	9	8
	se	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	n	2	110	3088	1023	3279	347	2197	2071	2612	2659	2444	504	10035	2018	3770	22072	1043	4021	107	5318	4586	8378	4592
PETROLEUM	Total days	72	15	102	0	0	0	0	27	0	8	1484	0	609	40	0	123	0	129	0	6	2	580	1057
	Average	72	5	36	0	0	0	0	7	0	3	495	0	56	30	0	14	0	29	0	2	2	20	5
	sd	0	3	45	0	0	0	0	0	0	0	753	0	31	0	0	14	0	46	0	1	0	35	16
	se	0	1	17	0	0	0	0	0	0	0	435	0	3	0	0	5	0	10	0	0	0	4	1
	n	1	6	7	0	0	0	0	5	0	7	3	0	111	3	0	9	0	22	0	7	1	85	713
FISHING	Total days	0	0	9	0	0	0	3	0	0	0	1	90	507	89	0	334	0	96	0	77	29	178	89
	Average	0	0	5	0	0	0	2	0	0	0	1	10	507	14	0	97	0	19	0	26	5	14	56
	sd	0	0	2	0	0	0	1	0	0	0	0	13	0	23	0	72	0	23	0	18	4	21	0
	se	0	0	2	0	0	0	1	0	0	0	0	4	0	7	0	23	0	10	0	7	1	4	0
	n	0	0	2	0	0	0	2	0	0	0	1	9	1	12	0	10	0	5	0	6	11	33	8
NAVAL	Total days	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	30	0	0	0	8	0	0	0
	Average	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4	0	0	0	8	0	0	0
	sd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
	se	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	n	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0	1	0	0	0
NON-TRADING	Total days	21	7	114	5	73	12	98	82	8	77	72	40	1215	263	22	502	0	365	22	543	650	1502	2184
	Average	14	7	23	0	18	7	9	14	2	12	9	12	22	14	4	32	0	8	11	40	28	42	12
	sd	0	0	33	0	16	0	10	0	0	22	11	17	47	21	3	56	0	10	13	101	103	132	48
	se	0	0	7	0	4	0	2	0	0	5	2	5	3	3	1	9	0	1	9	16	10	12	2
	n	7	1	24	4	19	6	28	13	9	18	24	10	187	55	5	42	0	97	2	41	99	113	845

Bioregions follow Figure 2: 1 – Antarctica; 2 – Arctic; 3 – Mediterranean (including the Black and Azov Seas); 4 – North West Atlantic (including region 19 – North American Great Lakes); 5 – North East Atlantic; 6 – Baltic; 7 – Wider Caribbean Sea; 8 – West Africa; 9 – South Atlantic; 10 – Central Indian Ocean; 11 – Arabian Seas; 12 – East Africa; 13 – East Asian Seas; 14 – South Pacific (including Hawaii); 15 – North East Pacific; 16 – North West Pacific; 17 – South East Pacific; 18 –New Zealand
Australian Provinces follow Figure 8: A Solanderian – Tropical; B Peronian – Warm Temperate (includes Lord Howe and Norfolk Islands); C Flindersian – Warm Temperate; D Dampierian – Tropical (includes Cocos, Keeling and Thursday Islands and Ashmore Reef). Provinces adjusted from Bennet and Pope (Knox 1963; Poore 1995)

Table E4: 2005 residency periods in port for commercial, petroleum, fishing, naval, and non-trading vessels.
Note: recreational vessels >25 m are included in non-trading; recreational vessels <25 m and IFFVs are not included (Lloyds MIU dataset).

DAFF Vessel Category	Bioregion/ Province	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	A	B	C	D
COMMERCIAL	Total days	10	601	15889	4964	13037	2310	15555	12759	13915	18012	15154	1342	58832	9098	18781	176436	6268	9499	652	31127	18282	25399	35908
	Average	3	5	6	6	4	6	8	7	6	7	7	4	6	5	5	8	7	3	7	6	4	3	8
	sd	1	3	9	8	4	5	15	11	9	8	10	5	11	16	6	15	12	5	9	9	10	11	25
	se	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	n	3	121	2978	895	3386	396	1953	1884	2635	2767	2201	395	10109	1825	3542	22197	975	3405	91	5633	4652	8113	4803
PETROLEUM	Total days	0	139	79	0	260	0	97	1316	6	550	10	0	2419	75	13	324	0	101	0	166	42	1816	5568
	Average	0	23	7	0	8	0	22	93	6	64	3	0	23	15	3	13	0	25	0	21	42	42	9
	sd	0	28	0	0	11	0	20	96	0	109	2	0	44	20	1	0	0	27	0	0	0	83	32
	se	0	11	0	0	2	0	8	23	0	26	1	0	4	9	1	0	0	14	0	0	0	15	1
	n	0	6	9	0	33	0	6	18	1	17	5	0	131	5	4	14	0	4	0	5	1	32	688
FISHING	Total days	55	0	0	0	46	0	0	1015	0	28	202	8	0	27	0	1	0	989	0	173	68	617	7
	Average	55	0	0	0	7	0	0	1015	0	28	25	4	0	7	0	1	0	62	0	25	6	82	2
	sd	0	0	0	0	8	0	0	0	0	0	24	1	0	3	0	0	0	146	0	8	7	105	1
	se	0	0	0	0	3	0	0	0	0	0	8	1	0	2	0	0	0	40	0	3	2	23	0
	n	1	0	0	0	7	0	0	1	0	1	8	2	0	4	0	1	0	13	0	8	12	20	4
NAVAL	Total days	41	0	0	0	0	0	14	0	0	0	0	0	0	0	9	0	0	0	0	4	0	0	0
	Average	41	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	0	4	0	0	0
	sd	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	se	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	n	1	0	0	0	0	0	6	0	0	0	0	0	0	0	4	0	0	0	0	1	0	0	0
NON-TRADING	Total days	7	19	1362	130	74	10	195	247	10	1177	286	116	2516	899	44	2890	348	770	3	776	2088	3656	9766
	Average	4	6	37	16	8	5	26	12	3	29	8	6	18	20	4	24	148	9	3	19	39	68	14
	sd	2	4	93	14	7	3	7	13	1	64	11	8	28	32	2	73	5	13	0	28	72	156	38
	se	1	2	14	4	2	2	2	3	1	11	2	2	2	5	1	7	2	2	0	4	7	20	1
	n	2	4	44	10	12	2	15	24	5	33	37	13	143	43	9	110	5	59	1	40	94	58	842

Bioregions follow Figure 2: 1 – Antarctica; 2 – Arctic; 3 – Mediterranean (including the Black and Azov Seas); 4 – North West Atlantic (including region 19 – North American Great Lakes); 5 – North East Atlantic; 6 – Baltic; 7 – Wider Caribbean Sea; 8 – West Africa; 9 – South Atlantic; 10 – Central Indian Ocean; 11 – Arabian Seas; 12 – East Africa; 13 – East Asian Seas; 14 – South Pacific (including Hawaii); 15 – North East Pacific; 16 – North West Pacific; 17 – South East Pacific; 18 –New Zealand

Australian Provinces follow Figure 8: A Solanderian – Tropical; B Peronian – Warm Temperate (includes Lord Howe and Norfolk Islands); C Flindersian – Warm Temperate; D Dampierian – Tropical (includes Cocos, Keeling and Thursday Islands and Ashmore Reef). Provinces adjusted from Bennet and Pope (Knox 1963; Poore 1995)

Table E5: 2006 residency periods in port for commercial, petroleum, fishing, naval, and non-trading vessels.
Note: recreational vessels >25 m are included in non-trading; recreational vessels <25 m and IFFVs are not included (Lloyds MIU dataset).

DAFF Vessel Category	Bioregion/ Province	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	A	B	C	D
COMMERCIAL	Total days	12	653	15258	4794	14403	1775	14966	12888	14128	19532	17585	1730	64327	7759	20025	182834	5457	12881	309	35034	19609	28713	40935
	Average	9	5	5	5	4	6	7	6	5	6	7	5	5	4	6	8	5	4	6	5	4	4	9
	sd	0	5	5	7	4	4	8	10	6	7	9	6	11	7	7	15	9	6	8	6	8	6	12
	se	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	n	1	141	3364	887	3726	343	2413	1934	3011	3204	2580	386	11999	2136	3660	24262	855	3982	54	7002	5250	9225	6459
PETROLEUM	Total days	72	2	141	0	20	0	21	2	0	67	6	0	1280	320	0	70	0	51	0	557	67	243	8081
	Average	13	0	16	7	0	0	7	2	0	8	6	71	15	80	0	11	0	7	11	14	13	13	12
	sd	15	0	29	0	9	0	5	0	0	0	0	0	37	157	0	16	0	6	0	0	0	22	43
	se	7	0	10	0	0	0	3	0	0	0	0	0	5	79	0	6	0	2	0	0	0	3	2
	n	4	0	9	3	0	0	3	1	0	8	1	3	67	4	0	8	0	8	6	24	6	72	476
FISHING	Total days	0	0	0	0	0	0	0	2	4	150	0	404	0	0	0	150	0	0	0	177	0	79	240
	Average	0	0	0	0	0	0	0	2	1	150	0	128	0	0	0	75	0	0	0	24	31	0	20
	sd	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	14	0	0	0	0	0	0	0
	se	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0
	n	0	0	0	0	0	0	0	1	3	1	0	3	0	0	0	2	0	0	0	5	0	6	8
NAVAL	Total days	0	0	0	0	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	224	0
	Average	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	224	0	0
	sd	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	se	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	n	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
NON-TRADING	Total days	0	20	367	32	321	7	285	405	0	568	67	0	2045	1882	349	1693	0	943	28	2197	665	3131	5553
	Average	0	12	5	11	13	7	79	7	72	14	4	17	17	42	16	18	42	12	0	11	37	30	18
	sd	0	5	13	0	15	0	0	0	0	0	0	0	22	61	17	22	0	46	0	62	20	106	41
	se	0	3	2	0	3	0	0	0	0	0	0	0	2	8	5	2	0	6	0	6	3	13	2
	n	0	4	40	3	28	1	20	10	0	16	13	0	152	66	10	107	0	58	5	100	58	68	335

Bioregions follow Figure 2: 1 – Antarctica; 2 – Arctic; 3 – Mediterranean (including the Black and Azov Seas); 4 – North West Atlantic (including region 19 – North American Great Lakes); 5 – North East Atlantic; 6 – Baltic; 7 – Wider Caribbean Sea; 8 – West Africa; 9 – South Atlantic; 10 – Central Indian Ocean; 11 – Arabian Seas; 12 – East Africa; 13 – East Asian Seas; 14 – South Pacific (including Hawaii); 15 – North East Pacific; 16 – North West Pacific; 17 – South East Pacific; 18 –New Zealand
Australian Provinces follow Figure 8: A Solanderian – Tropical; B Peronian – Warm Temperate (includes Lord Howe and Norfolk Islands); C Flindersian – Warm Temperate; D Dampierian – Tropical (includes Cocos, Keeling and Thursday Islands and Ashmore Reef). Provinces adjusted from Bennet and Pope (Knox 1963; Poore 1995)

Table E6: 2007 residency periods in port for commercial, petroleum, fishing and non-trading vessels.
Note: recreational vessels >25 m are included in non-trading; no naval vessels were recorded; recreational vessels <25 m and IFFVs are not included (Lloyds MIU dataset).

DAFF Vessel Category	Bioregion/ Province	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	A	B	C	D
COMMERCIAL	Total days	0	722	14637	3781	12908	1440	12401	10997	17959	20254	13113	1462	62856	6939	19212	171643	5405	12879	349	46731	18029	25306	42572
	Average	0	5	5	4	4	5	7	7	6	6	6	4	5	4	6	7	6	3	5	7	4	3	7
	sd	0	4	6	6	4	3	9	9	7	7	8	4	9	12	7	11	9	4	5	9	6	4	9
	se	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	n	0	143	3265	882	3455	318	1932	1704	3298	3241	2354	364	11898	1777	3396	23804	867	4046	79	6715	4757	8271	5911
PETROLEUM	Total days	0	89	81	0	47	0	211	502	0	281	24	31	2091	35	0	3	0	307	0	740	33	777	7683
	Average	0	8	8	0	3	0	27	26	0	31	7	5	19	6	0	0	0	27	0	47	8	41	26
	sd	0	16	0	0	0	0	17	28	0	0	0	3	23	0	0	0	0	0	0	86	10	62	75
	se	0	5	0	0	0	0	6	5	0	0	0	1	2	0	0	0	0	0	0	25	5	13	4
	n	0	12	8	0	10	0	7	28	0	17	4	7	105	5	0	4	0	10	0	12	4	21	349
FISHING	Total days	0	0	0	0	0	0	0	0	0	0	0	0	29	82	0	201	0	18	0	18	29	766	17
	Average	0	0	0	0	0	0	0	0	0	0	0	0	29	14	0	26	0	9	0	3	4	131	5
	sd	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	2	0	0	0
	se	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	1	0	0	0
	n	0	0	0	0	0	0	0	0	0	0	0	0	1	6	0	5	0	2	0	8	6	6	3
NON-TRADING	Total days	0	28	410	23	343	0	401	51	4	304	188	21	2597	1723	212	2173	45	1787	0	2472	3376	2001	4361
	Average	0	3	31	12	10	0	52	6	4	13	6	7	16	49	14	18	23	29	0	26	50	44	13
	sd	0	1	60	0	10	0	39	0	0	21	7	0	27	61	20	32	23	40	0	80	75	56	35
	se	0	0	14	0	2	0	9	0	0	4	1	0	2	9	6	3	17	5	0	8	8	8	2
	n	0	10	18	2	35	0	20	7	1	25	32	5	158	52	13	118	2	60	0	105	99	48	331

Bioregions follow Figure 2: 1 – Antarctica; 2 – Arctic; 3 – Mediterranean (including the Black and Azov Seas); 4 – North West Atlantic (including region 19 – North American Great Lakes); 5 – North East Atlantic; 6 – Baltic; 7 – Wider Caribbean Sea; 8 – West Africa; 9 – South Atlantic; 10 – Central Indian Ocean; 11 – Arabian Seas; 12 – East Africa; 13 – East Asian Seas; 14 – South Pacific (including Hawaii); 15 – North East Pacific; 16 – North West Pacific; 17 – South East Pacific; 18 –New Zealand

Australian Provinces follow Figure 8: A Solanderian – Tropical; B Peronian – Warm Temperate (includes Lord Howe and Norfolk Islands); C Flindersian – Warm Temperate; D Dampierian – Tropical (includes Cocos, Keeling and Thursday Islands and Ashmore Reef). Provinces adjusted from Bennet and Pope (Knox 1963; Poore 1995)

Table E7: Residency periods in port between 2002 and 2007 (combined) for commercial, petroleum, fishing, naval, and non-trading vessels. Note: recreational vessels >25 m are included in non-trading; recreational vessels <25 m and IFFVs are not included (Lloyds MIU dataset).

DAFF Vessel Category	Bioregion/ Province	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	A	B	C	D
COMMERCIAL	Total days	453	3603	89546	25801	80961	12377	88923	71421	80758	114784	91597	9710	353160	51069	117917	964028	35591	73851	2795	182847	111682	158201	194513
	Average	37	6	5	5	4	6	7	6	6	7	7	4	6	5	6	8	6	3	6	5	4	4	7
	sd	27	4	7	7	4	5	9	9	8	8	11	6	12	12	7	15	10	8	6	9	9	8	14
	se	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	n	12	698	18087	5296	20557	2117	12982	11655	15219	17067	13770	2412	62504	11825	21140	130039	5818	23472	509	35163	27596	49157	29817
PETROLEUM	Total days	181	392	579	0	563	0	410	2022	6	1201	1581	31	11528	509	60	727	0	1473	0	1504	215	7263	32058
	Average	29	17	13	7	10	0	27	40	6	0	54	27	27	28	6	0	0	40	11	19	13	26	12
	sd	8	26	0	0	14	0	15	47	0	37	153	3	33	52	6	19	0	38	0	30	12	49	39
	se	3	5	0	0	2	0	4	6	0	5	28	1	1	13	2	3	0	5	0	4	3	3	1
	n	7	27	42	3	57	0	18	60	1	63	30	10	594	17	10	52	0	51	6	51	22	356	2956
FISHING	Total days	55	0	9	0	46	0	3	1332	4	178	203	512	557	604	0	1826	0	2015	0	877	179	6044	2285
	Average	55	0	5	0	7	0	2	235	1	89	13	55	139	30	0	59	0	86	0	0	0	0	107
	sd	0	0	2	0	8	0	1	98	1	0	24	56	0	13	0	59	0	55	0	12	4	100	0
	se	0	0	2	0	3	0	1	35	0	0	8	14	0	2	0	11	0	8	0	2	1	8	0
	n	1	0	2	0	7	0	2	8	3	2	9	17	4	35	0	28	0	47	0	34	37	167	42
NAVAL	Total days	41	0	2	0	49	0	14	0	0	0	0	0	3	4	9	56	0	2	0	28	0	224	0
	Average	41	0	2	10	0	0	2	0	0	0	0	0	3	4	2	4	0	2	0	9	224	0	0
	sd	0	0	0	0	13	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	se	0	0	0	0	5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	n	1	0	1	0	6	0	6	0	0	0	0	0	1	2	4	16	0	1	0	3	0	1	0
NON-TRADING	Total days	210	83	3589	232	2534	304	1360	1322	222	2630	2822	267	15646	9089	899	11387	562	5477	129	9566	11348	17142	32856
	Average	32	5	23	0	63	23	30	9	17	19	20	9	23	42	11	24	0	16	0	20	34	46	17
	sd	2	0	51	0	28	10	14	19	8	36	57	11	44	79	14	46	8	27	5	55	70	111	51
	se	1	0	4	0	2	2	1	2	1	3	5	2	1	4	2	2	2	1	1	3	3	6	1
	n	13	24	169	28	182	16	113	87	30	110	124	34	856	327	64	506	13	339	40	439	485	395	2710

Bioregions follow Figure 2: 1 – Antarctica; 2 – Arctic; 3 – Mediterranean (including the Black and Azov Seas); 4 – North West Atlantic (including region 19 – North American Great Lakes); 5 – North East Atlantic; 6 – Baltic; 7 – Wider Caribbean Sea; 8 – West Africa; 9 – South Atlantic; 10 – Central Indian Ocean; 11 – Arabian Seas; 12 – East Africa; 13 – East Asian Seas; 14 – South Pacific (including Hawaii); 15 – North East Pacific; 16 – North West Pacific; 17 – South East Pacific; 18 –New Zealand

Australian Provinces follow Figure 8: A Solanderian – Tropical; B Peronian – Warm Temperate (includes Lord Howe and Norfolk Islands); C Flindersian – Warm Temperate; D Dampierian – Tropical (includes Cocos, Keeling and Thursday Islands and Ashmore Reef). Provinces adjusted from Bennet and Pope (Knox 1963; Poore 1995)

Hydroides dianthus

Hydroides dianthus is a calcareous tube-building polychaete that is widely distributed in a variety of habitats, including open coasts, partly brackish waters of bays, lagoons and ports (Link et al. 2009). This polychaete species provides numerous microhabitats for other species by means of its tubes and sediment enriched with tube fragments (Haines & Maurer 1980).

Common names:
Serpulid tube worm, limy tube worm.

Distribution:
Found in five of the 18 IUCN bioregions (see Figure 2).

Native: North West Atlantic (Eno et al. 1997).

Introduced: Mediterranean, North East Atlantic, Caribbean, West Africa, North East Pacific, South Atlantic and North West Pacific.

Larval period:
Planktonic for up to two weeks (citations in Link et al. 2009).

Temperature tolerance:
Inferred: -2.9 °C to 31.8 °C.
Physiological: No information available.

Inoculation likelihood: HIGH

Biofouling association rank – HIGH
H. dianthus is most likely to be introduced via vessel biofouling, but its planktonic larvae can also be transported in ballast water (Link et al. 2009). There was a possible additional introduction associated with the American oyster Crassostrea virginica (citations in Eno et al. 1997).

Transport pressure rank – MODERATE
Australian trade with the IUCN bioregions where H. dianthus is found represents 21.8% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 25.5% representing a moderate likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – NEGLIGIBLE
No information available.

Economic impacts – VERY LOW
H. dianthus may kill young oysters (C. virginica) by overgrowing them in its native range of eastern North America (Eno et al. 1997). It is also the host of certain nematode stages in eastern North America (Eno et al. 1997).

Social impacts/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **moderate**) by consequence for each value category (i.e. **negligible, very low, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Low	Moderate	Low	Low

Polydora nuchalis

Polydora nuchalis is a spionid polychaete, native to the eastern Pacific (Mexico). It is common to nearshore environments and is specifically known from aquaculture ponds. It feeds on detritus and other organic particulate matter.

Common names:
Spionid polychaete worm.

Distribution:
Found in two of the 18 IUCN bioregions (see Figure 2).

Native: North East Pacific.

Introduced: South Pacific (Hawaii).

Larval period:
Details about the larval period could not be found for this species, but the larval period for a closely related species, P. giardi, is 20 to 32 days (Day & Blake 1979).

Temperature tolerance:
Inferred: -1.5 °C to 32.1 °C.
Physiological: No information available.

Inoculation likelihood: LOW

Biofouling association rank – LOW
P. nuchalis is a sedentary infaunal species and not directly associated with biofouling, however, it has the potential to survive in sea-chests of vessels (Coutts & Dodgshun 2007).

Transport pressure rank – VERY LOW
Australian trade with the IUCN bioregions where *P. nuchalis* is found represents 10.0% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 12.8% representing a very low likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – NEGLIGIBLE
No information available.

Economic impacts – HIGH
P. nuchalis is inferred to have environmental impacts on other organisms due to competition for space and resources and through habitat modification (Bailey-Brock 1990).

Social impacts/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **negligible, high, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Low	High	Low	Low

Acartia tonsa

Acartia tonsa is a calanoid copepod with a body length of 1–1.5 mm. This species is found throughout the water column, predominantly in surface layers. In the Baltic Sea, this species is dominant in summer and autumn in the upper layers at 0–20 m depth (Zaiko 2004). It is known to develop in mass abundance and has very high reproductive potential (Zaiko 2004).

Common names:
None.

Distribution:
Found in eight of the 18 IUCN bioregions (see Figure 2).

Native: North East Pacific.

Introduced: Arctic, Mediterranean, North West Atlantic, North East Atlantic, Baltic, East Asian Seas and South East Pacific (Kurashova 2002).

Larval period:
Duration of the full developmental cycle from egg to mature adult is 30 to 33 days (Kurashova 2002).

Temperature tolerance:
Inferred: -2.9 °C to 31.8 °C.
Physiological: -1 °C to 32 °C (citations in Paffenhofer & Stearns 1988). Reproductive rate is low–under 10 °C (Zaiko 2004).

Inoculation likelihood: LOW

Biofouling association rank – LOW
A. tonsa was possibly introduced through transport on vessels hulls and/or in ballast water (Remy 1927; NOBANIS 2005). As it is a zooplankton species which produces diapause eggs, transport via ballast water is likely (Eno et al. 1997).

Transport pressure rank – LOW
Australian trade with the IUCN bioregions where *A. tonsa* is found represents 36.8% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 44.7% representing a low likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
A.tonsa has a tendency to become numerically dominant and may outcompete native planktonic copepods (citations in Zaiko 2004). It also can change energy/matter flows between pelagic and benthic compartments and modify trophic structure of invaded ecosystems (citations in Zaiko 2004). Some experimental studies have found that high levels of PSP toxin can be accumulated in copepod grazers such as *A. tonsa*, supporting the hypothesis that zooplankton may serve as PSP toxin vectors to higher trophic levels (citations in Zaiko 2004). *A. tonsa* may also have potential positive environmental impacts due to its high abundances and grazing abilities, which can serve as a potential biological control of algal blooms (citations in Zaiko 2004).

Economic impacts – NEGLIGIBLE
No information available.

Social impacts/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **moderate, negligible, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Low	Low	Low

Ampelisca abdita

Ampelisca abdita is a tube-dwelling suspension/deposit feeding amphipod. It grows to about 6 mm long and forms a narrow tube of 34 mm. In the Atlantic, *A. abdita* is commonly found amongst oyster beds and forms extensive mats within the sediments of protected bays (Hayes & Sliwa 2003).

Common names:
None.

Distribution:
Found in six of the 18 IUCN bioregions (see Figure 2).

Native: North West Atlantic, Wider Caribbean and the South Atlantic.

Introduced: North East Pacific, East Asian Seas and Central Indian Ocean.

Larval period:
No information available.

Temperature tolerance:
Inferred: -2.9 °C to 31.8 °C.
Physiological: Unknown.

Inoculation likelihood: LOW

Biofouling association rank – LOW
The invasion history of *A. abdita* is presumably linked with oyster movements and there is also the potential for the species to be transported via ballast water (Hayes & Sliwa 2003).

Transport pressure rank – LOW
Australian trade with the IUCN bioregions where *A. abdita* is found represents 35.7% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 44.8% representing a **low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
In San Francisco Bay, the high abundance of *A. abdita* allows it to interfere with the native mollusc *Macoma balthica* through predation, physical processes or competition for food (citations in Hayes & Sliwa 2003). It has also been suggested that *A. abdita* may limit recruitment and disrupt the feeding of established organisms (citations in Hayes & Sliwa 2003).

Economic impacts – NEGLIGIBLE
No information available.

Social impacts/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **moderate, negligible, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Low	Low	Low

Balanus eburneus

Balanus eburneus is a hermaphroditic (both sexes in one individual) sessile barnacle, reaching 2cm in size. It is found in fully saline to brackish waters of bays and estuaries. It occupies a variety of shallow marine substrates, including rocks and cobbles, man-made habitats (jetties, wharves, groynes, plastic debris) and also on biogenic (living) substrates such as mangroves, other crustaceans and shells of molluscs.

Common names:
Ivory barnacle.

Distribution:
Found in nine of the 18 IUCN bioregions (see figure 2).

Native: North West Atlantic and Wider Caribbean Sea.

Introduced: North East Atlantic, West Africa, Central Indian Ocean, South Pacific, North East Pacific, North West Pacific and South East Pacific.

Larval period:
Planktonic duration of seven to 13 days (Costlow & Bookhout 1957).

Temperature tolerance:
Inferred:-2.9 °C to 32.4 °C.
Physiological: 8 °C to 26 °C (Costlow & Bookhout 1957).

Inoculation likelihood: HIGH

Biofouling association rank – HIGH
B. eburneus is recognised as a primary benthic fouler, demonstrably associated with biofouling on hulls of vessels (Bishop 1951).

Transport pressure rank – HIGH
Australian trade with the IUCN bioregions where *B. eburneus* is found represents 61.2% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 76.9% representing a high likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – HIGH
B. eburneus was inferred to have environmental impacts on other organisms due to competition for space in its native and introduced ranges, and through habitat modification by creating a monoculture (e.g. Boudreaux et al 2009*)*

Economic impacts – LOW
B. eburneus is a nuisance fouler on commercial structures, including wharves, jetties and buoys, as well as biofouling on vessel hulls. As a biofouling barnacle, it is inferred to block seawater intakes for industrial (e.g. power station, factory) cooling systems and to foul mussels and oysters interfering with aquaculture production (e.g. Leppakoski & Gollasch 1999).

Social impacts/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – MODERATE
In recreational areas sharp shells may pose laceration risks (Leppakoski & Gollasch 1999).

Risks:

Multiplying the inoculation likelihood (i.e. **high**) by consequence in each value category (i.e. **high, low, negligible, moderate**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Extreme	Moderate	Low	High

Balanus glandula

Balanus glandula is predominantly an open coast species which can also inhabit estuaries. The species is found from the middle to upper intertidal area. Adults are about 1cm wide and are generally as tall as they are wide, but will grow into tall columnar shapes if crowded. The animals grow on rocks, pilings and sometimes other organisms. *B. glandula* is often the most abundant barnacle in the upper half of the intertidal zone (reaching densities of up to 70 000 individuals per square metre), and the most ubiquitous barnacle species on the Pacific coast. An individual can produce up to six broods of 1000 to 30 000 young per year.

Common names:
Acorn barnacle, white acorn barnacle, white buckshot barnacle.

Distribution:
Found in four of the 18 IUCN bioregions (see Figure 2).

Native: North East Pacific.

Introduced: West Africa, South Atlantic and North West Pacific.

Larval period:
Eggs are incubated in the mantle cavity for a period of approximately two months. Nauplii hatch and are planktonic for about one month (Barnes & Barnes 1956).

Temperature tolerance:
Inferred: -2.9 °C to 32.4 °C.

Physiological: Exact limits are unknown. Reproduction is thought to be restricted to sea temperatures below 17 °C (Barnes & Barnes 1956). In Argentina, *B. glandula* inhabit coastlines where mean temperature ranges between 4.3 °C and 21 °C. The species has been observed to survive high temperatures in laboratory and field conditions (e.g. 34 °C for 8.5 hours), without showing evidence of irreversible protein damage (Berger & Emlet 2007).

Inoculation likelihood: HIGH

Biofouling association rank – HIGH
Hulls and fenders of barges and tugboats have been found to be fouled with *B. glandula*. When scraped from fenders, egg masses have been found inside *B. glandula*, and when immersed in seawater, larvae have been observed to hatch from such egg masses (Kado & Nanba 2006). Larvae from biofouling organisms on cargo vessels from the United States are thought to be responsible for the establishment of this species at Japanese ports (Kado 2003).

Transport pressure rank – MODERATE
Australian trade with the IUCN bioregions where *B. glandula* is found represents 43.9% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 55.7% representing a moderate likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
This barnacle is a successful invader and has changed community structure of Argentinean intertidal communities, forming monospecific dense belts and displacing native barnacle species (Schwindt 2007).

Economic impacts – NEGLIGIBLE
No information available.

Social impacts/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **high**) by consequence in each value category (i.e. **moderate, negligible, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	Low	Low	Low

Balanus improvisus

Balanus improvisus is a hermaphroditic (both sexes in one individual) sessile barnacle, reaching 8–10mm in size. Found in fully saline to brackish water. In California, *B. improvisus* invades freshwater aqueducts as larvae, but adults cannot reproduce in freshwater. It occupies a variety of shallow marine substrates including rocks and cobbles, man-made habitats (jetties, wharves, groynes, plastic debris) and also on biogenic (living) substrates such as macro-algae, other crustaceans and shells of molluscs.

Common names:
Bay barnacle, acorn barnacle.

Distribution:
Found in 10 of the 18 IUCN bioregions (see Figure 2).

Native: North West Atlantic.

Introduced: Arctic, North East Atlantic, Baltic, South Atlantic, Arabian Seas, East Asian Seas, North East Pacific, North West Pacific and New Zealand.

The species has previously been identified in Western Australia, however, a subsequent survey of the region (Hewitt et al. 2000) did not detect its establishment in Australian waters.

Larval period:
Larval duration is between six to eight days at 25 °C (Dineen & Hines 1994).

Temperature tolerance:
Inferred:-2.9 °C to 35.3 °C.
Physiological: 1.8 °C to 22.7 °C (Zaiko, 2005).

Inoculation likelihood: HIGH

Biofouling association rank – HIGH
B. improvisus is recognised as a primary benthic fouler, demonstrably associated with biofouling on hulls of vessels (Bishop 1951; Gollasch et al. 1999; Gollasch 2002).

Transport pressure rank – HIGH
Australian trade with the IUCN bioregions where *B. improvisus* is found represents 76.8% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 95.6% representing a high likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
B. improvisus was inferred to have environmental impacts on other organisms through competition for space in its native and introduced ranges, and to create habitat modification by creating a monoculture (e.g. Lohse 2002; Qvarfordt et al 2006).

Economic impacts – HIGH
B. improvisus has been inferred to block seawater intakes for industrial (e.g. power station, factory) cooling systems in the Baltic Sea and to foul mussels and oysters interfering with aquaculture production (Gollasch et al. 1999; Leppakoski & Gollasch 1999).

Social impacts/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – MODERATE
In recreational areas sharp shells may pose laceration risks (Leppakoski & Gollasch 1999).

Risks:

Multiplying the inoculation likelihood (i.e. **high**) by consequence in each value category (i.e. **moderate, high, negligible, moderate**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	Extreme	Low	High

Briarosaccus callosus

Briarosaccus callosus is a cosmopolitan rhizocephalan barnacle that parasitises decapod crustaceans. Due to its very high reproductive potential, this species can rapidly infest decapod crustacean populations (Isaeva et al. 2005).

Common names:

Parasitic barnacle.

Distribution:

Found in four of the 18 IUCN bioregions (see Figure 2).

North East Atlantic, Baltic, North East Pacific and North West Pacific. All regions are considered cryptogenic given the native region is unknown.

Larval period:

Larvae swim freely for around a month before settling and parasitising an appropriate host (Isaeva et al. 2005).

Temperature tolerance:

Inferred: -2.9 °C to 32.4 °C.
Physiological: Development of larvae ceases and no metamorphosis at 4 °C. Larvae can develop at temperatures of 6 ˚C to 8 °C (Kashenko & Korn 2002). Upper temperature range unknown.

Inoculation likelihood: MODERATE

Biofouling association rank – LOW

No information available. Vessel would need to carry a crustacean host infected with *B. callosus* in order for this species to be introduced via biofouling.

Transport pressure rank – MODERATE

Australian trade with the IUCN bioregions where *B. callosus* is found represents 42.3% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 52.7% representing a low likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE

No information available.

Economic impacts – HIGH

This species parasitises various species of commercially important crabs, including species of *Lithodes, Paralithodes* and *Paralomis* (Isaeva et al. 2005). A high prevalence of infection can conceivably reduce commercial stocks (Bower & Meyer 1999).

Social impacts/cultural impacts – NEGLIGIBLE

No information available.

Human health impacts – NEGLIGIBLE

No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **moderate**) by consequence for each value category (i.e. **moderate, high, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Low	High	Low	Low

Callinectes sapidus

Callinectes sapidus lives in estuaries and on the coast from low tide down to a depth of 35 m on muddy and sandy sea floors. Females mate in the upper reaches of estuaries, then move to the mouth of the estuary or nearshore coastal waters to spawn. In its native habitat on the Atlantic Coast from Nova Scotia to Uruguay, it serves as an important commercial and recreational fishery for human consumption (Nehring et al. 2008). *C. sapidus* produce huge numbers of offspring (about one to two million, but up to eight million eggs per female) that grow quickly and rapidly become sexually mature. *C. sapidus* can live under a wide range of chemical and physical environmental conditions and are omnivores and good swimmers–usually necessary prerequisites to become a successful invader (Nehring et al. 2008).

Common names:
Blue crab.

Distribution:
Found in eight of the 18 IUCN bioregions (see Figure 2).

Native: North West Atlantic, Wider Caribbean Sea and South Atlantic.

Introduced: Mediterranean, North East Atlantic, Baltic, South Pacific and North West Pacific.

Larval period:
Typical time for development through the seven zoeal stages is between 30 and 50 days before metamorphosis to the megalopal stage. The megalopa then persists between six and 58 days (Hill 2004).

Temperature tolerance:
Inferred: -2.9 °C to 31.8 °C
Physiological: 15 °C to 30 °C (Hill 2004). Growth occurs between 15 °C and 30 °C, but is prevented at temperatures below 10 °C. Low temperatures (<10 °C) prevent moulting and decrease growth rates in *C. sapidus* (Hill 2004), while a state of hibernation is induced in *C. sapidus* at temperatures below 5 °C. Generally, growth occurs at temperatures over 15 °C, and is mostly unaffected by salinity conditions (Hill 2004). Hatching of *C. sapidus* eggs requires water temperatures higher than 19 °C (citations in Nehring et al. 2008).

Inoculation likelihood: LOW

Biofouling association rank – VERY LOW
Ballast water was suspected as the main vector for introducing this species into European waters because *C. sapidus* were predominantly found in port regions where ballast water discharges frequently occur (citations in Nehring et al. 2008). However, the recent record of *C. sapidus* in the Weser estuary (Germany) has been attributed to translocation via biofouling (Nehring et al. 2008). *C. sapidus* is also thought to have been introduced to Japan in sea-chests (Otani 2004).

Transport pressure rank – MODERATE
Australian trade with the IUCN bioregions where *C. sapidus* is found represents 55.7% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 69.1% representing a moderate likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – NEGLIGIBLE
No information available.

Economic impacts – HIGH
Juvenile populations of clams, mussels and oysters are the preferred foods of *C. sapidus* (Hill 2004) and this species has the potential to impact on commercial populations of these organisms. *C. sapidus* is nominated as one of the 100 'worst invasive alien species in the Mediterranean' based on its impacts on biodiversity and fisheries (citations in Nehring et al. 2008).

Social impacts/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **negligible, high, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Low	High	Low	Low

Carcinoscorpius rotundicauda

Carcinoscorpius rotundicauda is found in shallow waters on soft sandy substrates. It typically occupies marine habitats, but it has also been found in rivers with low salinities. *C. rotundicauda* is predominantly a scavenger species and feeds on mollusca, arthropoda and detritus. Females can lay 60 000 to 120 000 eggs in batches of a few thousand at a time, with eggs taking up to two weeks to hatch. Individuals take 11 years to reach sexual maturity, after which they can live up to 14 more years.

Common names:
Bangladesh horseshoe crab, mangrove horseshoe crab.

Distribution:
Found in three of 18 the IUCN bioregions (see Figure 2).

Native: Central Indian Ocean, East Asian Seas and North West Pacific.

Introduced: No information available.

Larval period:
After hatching, trilobite larvae remain in the water column for around 21 days before settling onto soft sediments (Lee & Morton 2005).

Temperature tolerance:
Inferred: -2.9 °C to 32.7 °C.
Physiological: Minimum 22 °C, maximum 35 °C. Moulting continues when temperatures remain >28 °C, and are halted at <22 °C. Low temperatures have also been found to reduce moulting hormone levels to a critical degree in a closely related species, *Limulus polyphemus* and hence, suspend the moulting process at temperatures of <20 °C. The optimal temperature for development of *L. polyphemus* larvae ranges from 25 °C to 30 °C (Jegla & Costlow 1982), while the maximum survival temperature is 35 °C (Ehlinger & Tankersley 2004).

Inoculation likelihood: LOW

Biofouling association rank – VERY LOW
No information available.

Transport pressure rank – HIGH
Australian trade with the IUCN bioregions where *C. rotundicauda* is found represents 61.8% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 77.7% representing a high likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – NEGLIGIBLE
No information available.

Economic impacts – NEGLIGIBLE
No information available.

Social impacts/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
The eggs and flesh of *C. rotundicauda* in parts of South East Asia have been found to contain tetrodotoxin (TTX) which is not suitable for human consumption. The eggs of the cooked animal have been traditionally eaten, which has caused food poisoning of people in Thailand (Tanu & Noguchi 1999).

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence in each value category (i.e. **negligible, negligible, negligible, high**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Low	Low	Low	High

Charybdis japonica

Charybdis japonica is a dioecious (two sexes), commercially important crab species in its native region of the North West Pacific that reach 12cm in size. *C. japonica* is found primarily in bays and estuaries, but can also survive on the open coast. Juvenile *C. japonica* have been associated with seagrass meadows (Huh & An 1998, cited in Smith et al. 2003) and soft mud, sand and shell habitats in New Zealand (Gust & Inglis 2006).

Common names:
Lady crab, Asian paddle crab, Asian crab, swimming crab.

Distribution:
Found in two of the 18 IUCN bioregions (see Figure 2).

Native: North West Pacific, particularly coastal regions of China, Japan, Korea, Taiwan and Malaysia (Smith et al. 2003).

Introduced: New Zealand.In 2000, a single male specimen was identified in Adelaide (Gilliland, Primary Industries and Resources, South Australia, pers. comm.; Hayes & Sliwa 2003), but subsequent surveys did not detect any additional specimens (Cohen et al. 2002).

Larval period:
Information about this species' larval period could not be found, but the closely related species, *C. hellerii*, has a larval duration of 44 days (Dineen et al. 2001).

Temperature tolerance:
Inferred: -1.5 °C to 31.5 °C.
Physiological: No information available.

Inoculation likelihood: MODERATE

Biofouling association rank – MODERATE
C. japonica is not a sessile or sedentary species, but is associated with biofouling, and the genus has been identified in sea-chests of vessels (Coutts & Dodgshun 2007).

Transport pressure rank – LOW
Australian trade with the IUCN bioregions where *C. japonica* is found represents 39.1% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 49% representing a low likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
C. japonica is a predatory species demonstrated to cause direct impacts on benthic species living in or on soft and hard substrates. Additionally, *C. japonica* is a known carrier of the White Spot Syndrome Virus (WSSV) (Maeda et al. 1998; Hayes & Sliwa 2003), which may affect a wide range of native crustaceans including shrimps and crabs.

Economic impacts – EXTREME
C. japonica is a known carrier of a World Organisation for Animal Health (OIE) listed species, WSSV (Maeda et al. 1998; Hayes & Sliwa 2003) which has the potential to affect several commercially important Australian wild stocks and aquaculture shrimp, lobster and crab species. *C. japonica* is also a predator of aquaculture species, such as the blue mussel, *Mytilus galloprovincialis* (Oikawa et al. 2004).

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – EXTREME
C. japonica has been demonstrated to bioaccumulate toxins (e.g. paralytic shellfish poisoning) through predation on filter feeding molluscs (Oikawa et al. 2004). As a consequence, human consumption of *C. japonica* during or immediately following a toxic algal bloom event could transmit the toxins in sufficient quantities to cause human illness.

Risks:

Multiplying the inoculation likelihood (i.e. **moderate**) by consequence for each value category (i.e. **moderate, extreme, negligible, extreme**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	Extreme	Low	Extreme

Chthamalus proteus

A small barnacle about 1cm in diameter that inhabits the high or supra-tidal zones of protected harbours and embayments growing on pilings and other surfaces (Southward et al. 1998).

Common names:
Atlantic barnacle, Caribbean barnacle.

Distribution:
Found in four of the 18 IUCN bioregions (see Figure 2).

Native: South Atlantic and Wider Caribbean.

Introduced: East Asian Seas and South Pacific.

Larval period:
The larval period is short and varies with temperature and diet. There are six naupliar stages followed by a cyprid. At 28 °C, the earliest cyprids could develop was within 10 days (Zabin 2005).

Temperature tolerance:
Inferred: -0.6 °C to 32.1 °C.
Physiological: 16 °C to 38 °C (Zabin 2005).

Inoculation likelihood: MODERATE

Biofouling association rank – HIGH

This biofouling organism is thought to have been introduced to Hawaii from the Caribbean and then distributed throughout the island chain on the hulls of vessels and boats (DeFelice et al. 1998). It is now commonly seen growing above the water line on vessel hulls in Hawaii. It is thought to be only a matter of time before the species is introduced via this vector to other areas in the Pacific (Southward et al. 1998).

Transport pressure rank – LOW

Australian trade with the IUCN bioregions where *C. proteus* is found represents 29.9% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 38.0% representing a low likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE

This species is potentially a nuisance biofouling organism. It may cause competition for space with native and non-indigenous invertebrates in the high intertidal zone (Southward et al. 1998). In Hawaii this barnacle has established itself by exploiting a largely vacant niche (i.e. supratidal zone). Although impacts in Hawaii appear relatively benign (Southward et al. 1998), at high densities the barnacle may negatively impact the limpet *Siphonaria normalis* (Zabin 2005).

Economic impacts – NEGLIGIBLE

No information available.

Social/cultural impacts – NEGLIGIBLE

No information available.

Human health impacts – NEGLIGIBLE

No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **moderate**) by consequence for each value category (i.e. **moderate, negligible, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	Low	Low	Low

Crangonyx floridanus

Crangonyx floridanus is a freshwater amphipod that can tolerate low salinities.

Common name:
Florida crangonyctid.

Distribution:
Found in three of the 18 IUCN bioregions (see Figure 2).

Native: Wider Caribbean.

Introduced: North East Pacific and North West Pacific.

Larval period:
Unknown.

Temperature tolerance:
Inferred: -2.9 °C to 32.4 °C.
Physiological: No information available.

Inoculation likelihood: LOW

Biofouling association rank – VERY LOW

The introduction of *C. floridanus* into Japan and Oregon has been attributed to ballast water (Zhang 1997). *C. floridanus* has not been recorded as a biofouling species.

Transport pressure rank – LOW

Australian trade with the IUCN bioregions where *C. floridanus* is found represents 38.3% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 48.2% representing a low likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE

Widely invasive species in Japan (Kanada et al. 2007).

Economic impacts – NEGLIGIBLE

No information available.

Social/cultural impacts – NEGLIGIBLE

No information available.

Human health impacts – NEGLIGIBLE

No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **moderate, negligible, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Low	Low	Low

Dikerogammarus villosus

Dikerogammarus villosus is a predatory freshwater amphipod. Its preferred environment is freshwater and brackish waters of lakes, rivers, estuaries and canals. *D. villosus* can tolerate salinities up to 24 ppt.

Common name:
Killer shrimp.

Distribution:
Found in two of the 18 IUCN bioregions (see Figure 2).

Native: Mediterranean.

Introduced: Baltic.

Larval period:
No larval stage–eggs are developed in the ventral brood chamber of the female. The species' young resemble adults and reach sexual maturity rapidly.

Temperature tolerance:
Inferred: -2.9 °C to 29.7 °C.
Physiological: 20 °C to 35°C.

Inoculation likelihood: VERY LOW

Biofouling association rank – LOW
Invasion into North America predicted via ballast tanks (Crosier & Molloy 2008). This species lives on solid surfaces of all kinds.

Transport pressure rank – EXTREMELY LOW
Australian trade with the IUCN bioregions where *D. villosus* is found represents 5.4% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 6.2% representing an extremely low likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – EXTREME
D. villosus colonises a wide variety of substrates and is capable of adapting to a wide range of habitats. It is able to survive fluctuations in temperature, salinity and oxygen levels (Crosier & Molloy 2008). *D. villosus* is a voracious predator of other macroinvertebrates, including other gammarids, which can result in displacement or local extinction of native species, thereby reducing biodiversity (Crosier & Molloy 2008). *D. villosus* has been observed attacking small fish, which raises concern over whether vulnerable life stages (eggs, larvae and juveniles) of vertebrates may also be at risk (Crosier & Molloy 2008). *D. villosus* may also be an intermediate host of acanthocephalan worms (a parasite of birds and fish) (Crosier & Molloy 2008).

Economic impacts – NEGLIGIBLE
No information available.

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. very low) by consequence for each value category (i.e. extreme, negligible, negligible, negligible) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Very low	Very low	Very low

APPENDIX F
Species datasheet

Eriocheir sinensis

Eriocheir sinensis is a migrating species of crab found in rivers, estuaries and marine habitats of cold-temperate to tropical areas. *E. sinensis* is tolerant to highly polluted water and typically occupies lower shorelines to about 10 m in depth. *E. sinensis* is a culinary delicacy in Asia and supports a US$1.25 billion per annum aquaculture industry in China (Gollasch 2006). It has been used as bait for eel fishing and to produce fish meal and cosmetic products. The species has also been used as fertilizer in agriculture. This species has been nominated as among 100 of the 'world's worst' invaders.

Common name:

Chinese mitten crab.

Distribution:

Found in seven of the 18 IUCN bioregions (see Figure 2).

Native: North West Pacific.

Introduced: Mediterranean, North West Atlantic, North East Atlantic, Baltic, Wider Caribbean Sea and North East Pacific.

Larval period:

The larval duration for *E. sinensis* is 43 to 90 days (Herborg et al. 2007). The species is catadromous–its free living planktonic larvae develop predominantly in saline water and require salinity greater than 15 ppt, although they spend much of the remainder of their lifecycle in freshwater (Herborg et al. 2007).

Temperature tolerance:

Inferred: -2.9 °C to 32.4 °C. Physiological: Adult survival: 4 °C to 32 °C (Cohen & Weinstein 2001). Successful development of larvae occurs only at temperatures > 12 °C. No survival of first zoea has been observed below 9 °C (Anger 1991). Juvenile growth rates stops below 7 °C and above 30 °C (Cohen & Weinstein 2001).

Inoculation likelihood: MODERATE

Biofouling association rank – MODERATE

Some specimens in empty 'shells' of cirripeds have been reported on a vessel's hull (Gollasch 2006). Two adult mitten crabs (4–5cm) were found in the sea-chest of a vessel that travelled from Bremen, China, to Hamburg, Germany (citations in Herborg et al 2003).

Transport pressure rank – MODERATE

Australian trade with the IUCN bioregions where *E. sinensis* is found represents 52.2% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 64.4% representing a moderate likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – HIGH

E. sinensis impacts freshwater and estuarine ecosystems on a number of levels. It has an opportunistic diet including algae, detritus, and a variety of macroinvertebrates (citations in Gollasch 2006). Juvenile *E. sinensis* form dense colonies and create burrows in the intertidal portions of streams, a process which has caused erosion of stream banks in both Europe and the United States (citations in Gollasch 2006).

Economic impacts – HIGH

The monetary impact caused by *E. sinensis* in German waters since 1912 totals to approximately 80 million (Gollasch 2006). This species steals bait and damages fishing gear which hinders commercial and recreational fishing (citations in Gollasch 2006). Crabs may also feed on trapped fish in commercial aquaculture ponds. *E. sinensis* may also block water intakes in irrigation and water supply schemes (Gollasch 2006). In California, *E. sinensis* has disrupted water diversion plants with large numbers of downstream-migrating crabs becoming trapped in holding tanks meant to keep fish out of turbines. This has caused fish mortality; and high costs are spent to prevent the crab's entry (citations in Gollasch 2006).

Social/cultural impacts – HIGH

In California, adult *E. sinensis* have become a major nuisance to anglers, taking a variety of baits including ghost shrimp and shad (Washington Sea Grant Program 2000).

Human health impacts – HIGH

E. sinensis is an intermittent host for the Oriental lung fluke. Mammals, including humans, can become infested by eating raw or poorly cooked mitten crabs (Gollasch 2006).

Risks:

Multiplying the inoculation likelihood (i.e. moderate) by consequence for each value category (i.e. high, high, high, high) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	High	High	High

Gammarus tigrinus

Gammarus tigrinus is an amphipod that is 4–11 mm in length. It is a benthic species which inhabits a range of environments, including sand and coarse stone substrates. *G. tigrinus* is typically found in rivers, with salinities ranging from freshwater to 25 ppt.

Common names:
Amphipod, freshwater shrimp.

Distribution:
Found in three of the 18 IUCN bioregions (see Figure 2).

Native: North West Atlantic.

Introduced: Baltic and North East Atlantic.

Larval period:
No larval stage–eggs are developed in the ventral brood chamber of the female. Egg incubation period is about 10 days and females are sexually mature after four weeks (Chambers 1977).

Temperature tolerance:
Inferred: -2.9 °C to 29.6 °C.
Physiological: 0 °C to 35 °C (SEPA 2005).

Inoculation likelihood: LOW

Biofouling association rank – MODERATE
This species is thought to have been introduced to the United Kingdom through ballast water (Swedish Environmental Protection Agency [SEPA] 2005) and to Germany as fish food. No information was available in relation to biofouling association.

Transport pressure rank – EXTREMELY LOW
Australian trade with the IUCN bioregions where *G. tigrinus* is found represents 7.0% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 7.9% representing an **extremely low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
G. tigrinus has become widespread where it has been introduced to rivers in Germany, Netherlands and other countries in the Baltic and North East Atlantic regions. *G. tigrinus* is an omnivore and has been shown to outcompete and displace native amphipods (SEPA 2005). Since its introduction, it has become the most common amphipod in German rivers, however, following the introduction of *D. villosus*, it has become less dominant.

Economic impacts – NEGLIGIBLE
No information available.

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:
Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **moderate, negligible, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Low	Low	Low

Gmelinoides fasciatus

Gmelinoides fasciatus is able to survive a wide range of temperatures and oxygen concentrations (Berezina 2007). It is a freshwater amphipod, with a salinity tolerance of 4 ppt in males and 6 ppt in females. *G. fasciatus* cannot reproduce in salinities higher than 2 ppt (Berezina & Panov 2004). It is widespread in different aquatic ecosystems from low salinity lakes to estuaries (Berezina 2007). *G. fasciatus* inhabits silt, sandy, stony and woody substrates and concentrates in macrophyte and macroalgae beds (Berezina 2007). *G. fasciatus* is one of the most successful invaders in eastern Europe and Siberia (Berezina et al. 2009). It consumes detritus, algae and aquatic plants as well as small benthic and zooplankton organisms (Berezina 2007). The species can tolerate severe eutrophication (Berezina 2007). In some regions, *G. fasciatus* was intentionally introduced to enrich fish production (Berezina 2007). *G. fasciatus* has a short life cycle and high fecundity which means it can reach high densities in a short period (Berezina 2007; Berezina et al. 2009).

Common name:
Baikalian amphipod.

Distribution:
Found in two of the 18 IUCN bioregions (see Figure 2).

Native: Inland waters of Asia and Serbia (CORPI 2008).

Introduced: Baltic and North West Pacific bioregions as well as freshwaters of eastern Europe and Siberia (Berezina et al. 2009).

Larval period:
No information.

Temperature tolerance:
Inferred: -2.9 °C to 22.5 °C (Baltic bioregion)
Physiological: Female *G. fasciatus* were found with fecund eggs in the Neva Estuary (Baltic Sea basin) at a water temperature of 27 °C (Berezina 2007).

Inoculation likelihood: LOW

Biofouling association rank – LOW
G. fasciatus was intentionally introduced to some regions to enrich fish production (Berezina 2007). No information available on the likelihood of this species occurring as biofouling.

Transport pressure rank – LOW
Australian trade with the IUCN bioregions where *G. fasciatus* is found represents 32.6% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 41.3% representing a low likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – HIGH
G. fasciatus has had a high ecological impact in the aquatic ecosystems of Russia where its spread has led to changes in pre-existing biota, loss of species diversity and alterations to food webs (Berezina 2007). It causes alterations in community structures and a decrease in the native macroinvertebrate populations (Berezina et al. 2009). *G. fasciatus* is also able to transfer a parasite that can cause disease in ducks (Sidorov, cited in Berezina 2007).

Economic impacts – NEGLIGIBLE
No information available.

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **high, negligible, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	Low	Low	Low

Hemigrapsus sanguineus

Hemigrapsus sanguineus inhabits hard-bottom intertidal habitats and sometimes shallow subtidal habitats, with highest densities occurring at the middle and lower intertidal elevations (Benson 2005). This species is an opportunistic omnivore, feeding on macroalgae, salt marsh grass, larval and juvenile fish, and small invertebrates such as amphipods, gastropods, bivalves, barnacles and polychaetes. *H. sanguineus* has a high fecundity and females are capable of producing 50 000 eggs per clutch with three to four clutches per breeding season.

Common names:
Asian shore crab, Japanese shore crab.

Distribution:
Found in four of the 18 IUCN bioregions (see Figure 2).

Native: North West Pacific.

Introduced: North West Atlantic, Mediterranean and North East Atlantic.

Larval period:
Larval planktonic stage lasts for one month under optimal temperature and salinity conditions (Epifanio et al. 1998).

Temperature tolerance:
Inferred: -2.9 ˚C to 31.5 °C.
Physiological: Minimum temperature required for development of larvae into juvenile stage is 15 °C (Epifanio et al. 1998). In its native and introduced range, this species is not reported at locations where average summer sea surface temperatures are below 12.6 °C. The adults are recorded as surviving in temperatures from 0.8 °C to 26.7 °C in New Jersey (McDermott 1998).

Inoculation likelihood: MODERATE

Biofouling association rank – LOW
There is potential for *H. sanguineus* to be transported in niche areas such as sea-chests, but no specific information is available.

Transport pressure rank – MODERATE
Australian trade with the IUCN bioregions where *H. sanguineus* is found represents 43.4% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 53.4% representing a moderate likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – HIGH
The very broad diet of *H. sanguineus* suggests it has the potential to affect populations of native species such as crabs, fish and shellfish by disrupting the food web (Benson 2005). It is also a competitor with native crabs for habitat and food. Recent trends in the United States show numbers of *H. sanguineus* are steadily increasing, while native crab populations are declining (Benson 2005). Since its introduction to the United States in 1988, it has become the dominant crab species in rocky intertidal habitats at many locations.

Economic impacts – MODERATE
Predates on commercial species, such as blue mussels *Mytilus edulis*, soft-shell clams *Mya arenaria* and oysters *Crassostrea virginica* (Benson 2005), as well as juvenile lobsters *Homarus americanus*.

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **moderate**) by consequence for each value category (i.e. **high, moderate, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	High	Low	Low

Loxothylacus panopaei

Loxothylacus panopaei is a rhizocephalan barnacle that is a parasite of decapod crustaceans. The host range of *L. panopaei* includes at least nine species of xanthid crabs, including commercially important *Callinectes* species.

Common name:
Parasitic barnacle.

Distribution:
Found in two of the 18 IUCN bioregions (see Figure 2).

Native: Wider Caribbean Sea.

Introduced: North West Atlantic

Larval period:
Larval development is completed in 84 hours.

Temperature tolerance:
Inferred: 10.5 ˚C to 31.8 °C.
Physiological: For reproduction: 11 ˚C to 26 °C (National Estuarine and Marine Exotic Species Information System [NEMESIS] 2005). For survival: unknown.

Inoculation likelihood: VERY LOW

Biofouling association rank – LOW
Introduced to Chesapeake Bay in association with aquaculture transfers (oysters) from the Gulf of Mexico (citations in NEMESIS 2005a).

Transport pressure rank – EXTREMELY LOW
Australian trade with the IUCN bioregions where *L. panopaei* is found represents 4.5% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 5.5% representing an **extremely low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – HIGH
As a parasite on decapod crustaceans, *L. panopaei* usually destroys the gonads of the host and inhibits moulting. *L. panopaei* may cause indirect effects on other trophic levels, such as the predators and prey of its host species (NEMESIS 2005a).

Economic impacts – HIGH
As a parasite of the commercially important blue crab (*C. sapidus*), *L. panopaei* is believed to cause significant economic loss in the Gulf of Mexico (Vasquez-Lopez et al. 2006).

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **very low**) by consequence for each value category (i.e. **high, high, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Moderate	Very low	Very low

Pachygrapsus fakaravensis

Pachygrapsus fakaravensis is a medium-sized intertidal crab that inhabits rocky shores. *P. fakaravensis* is a scavenger that feeds on plant and animal debris in the intertidal zone (Eldredge & Smith 2001).

Common name:
Polynesian grapsid crab.

Distribution:
Found in one of the 18 IUCN bioregions (see Figure 2).

Native: South Pacific (French Polynesia).

Introduced: South Pacific (Hawaii).

Larval period:
Has a planktonic larval stage, but larval duration is unknown.

Temperature tolerance:
Inferred: -2.9 °C to 32.1 °C.
Physiological: No information available.

Inoculation likelihood: LOW

Biofouling association rank – MODERATE

This species is thought to have been introduced to Hawaii via ballast water (Eldredge & Smith 2001). No references are available with respect to the species' biofouling association.

Transport pressure rank – EXTREMELY LOW

Australian trade with the IUCN bioregions where *P. fakaravensis* is found represents 5% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 6.6% representing an extremely low likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE

Environmental impact is unknown, but species may compete with native intertidal grapsid crabs for food and shelter (Eldredge & Smith 2001).

Economic impacts – NEGLIGIBLE

No information available.

Social/cultural impacts – NEGLIGIBLE

No information available.

Human health impacts – NEGLIGIBLE

No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **moderate, negligible, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Low	Low	Low

Rhithropanopeus harrisii

Rhithropanopeus harrisii is a dioecious (two sexes) crab species, reaching 12cm in size. This species is found in estuaries and salt marshes in both native and introduced regions, tolerating a wide range of salinities, including freshwater. It is commonly associated with oyster beds and areas of man-made disturbance such as canals and waterways (Gollasch et al. 1999; Leppakoski & Gollasch 1999).

Common names:
Harris mud crab, white-fingered mud crab, Zuiderzee crab.

Distribution:
Found in eight of the 18 IUCN bioregions (see Figure 2).

Native: North West Atlantic and Wider Caribbean Sea.

Introduced: Mediterranean, North East Atlantic, Baltic, South Atlantic, North East Pacific and North West Pacific.

Larval period:
14 to 50 days (Turoboyski 1973).

Temperature tolerance:
Inferred: -2.9 °C to 32.4 °C.
Physiological: -2.9 °C to 35 °C (Turoboyski, 1973). Larvae can survive between 18 °C and 30 °C (Turoboyski 1973).

Inoculation likelihood: MODERATE

Biofouling association rank – MODERATE
R. harrisii is not a sessile or sedentary species, but is associated with biofouling of oysters and mussels, and has the potential to survive in sea-chests of vessels (Coutts & Dodgshun 2007).

Transport pressure rank – MODERATE
Australian trade with the IUCN bioregions where *R. harrisii* is found represents 55.7% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 68.7% representing a moderate likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
R. harrisii is a small predatory species that is inferred to cause direct impacts on other crabs, as well as predation on benthic species living in or on soft and hard substrates (Gollasch et al. 1999).

Economic impacts – HIGH
R. harrisi may prey upon newly settled spat of commercially important oysters and mussels (Leppakoski & Gollasch 1999). Reports of crabs clogging water intakes have been documented in northern Europe (Gollasch et al. 1999; Leppakoski & Gollasch 1999).

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **moderate**) by consequence for each value category (i.e. **moderate, high, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	High	Low	Low

Solidobalanus fallax

Solidobalanus fallax is a hermaphroditic (both sexes in one individual) sessile, warm-water barnacle. It is found primarily in bays and estuaries, but can also persist on the open coast. In Europe, the species is primarily found on biological substrata such as algae, cnidarians, molluscs and crustaceans (Southward et al. 2004), but also settles on plastic bags and nets, and objects such as crab and lobster pots.

Common name:
Warm-water barnacle.

Distribution:
Found in two of the 18 IUCN bioregions (see Figure 2).

Native: West Africa.

Introduced: North East Atlantic.

Larval period:
Eight-day planktonic period before reaching the cyprid stage (Korn & Elfimov 1999).

Temperature tolerance:

Inferred: -1.5 ˚C to 31.7 °C.
Physiological: Unknown.

Inoculation likelihood: LOW

Biofouling association rank – LOW
S. fallax is a sessile species, but has a preferential association with biological substrates making its association with biofouling reliant on well established biofouling assemblages.

Transport pressure rank – VERY LOW
Australian trade with the IUCN bioregions where S. fallax is found represents 8.6% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 10.4% representing a very low likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – EXTREME
S. fallax settles on biogenic substrate including algae, molluscs, crustaceans and the habitat-forming sea-fan Eunicella verrucosa where its presence is inferred to cause negative impacts by overgrowth and smothering (Southward et al. 2004).

Economic impacts – MODERATE
S. fallax is a nuisance fouler on commercial maritime structures including wharves, jetties and buoys, as well as biofouling on vessel hulls. As a biofouling barnacle, it is inferred to block seawater intakes for industrial (e.g. power station, factory) cooling systems and to foul mussels and oysters–interfering with aquaculture production (Leppakoski & Gollasch 1999; Southward et al. 2004).

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **extreme, moderate, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	Moderate	Low	Low

Sphaeroma annandalei

Sphaeroma annandalei is an isopod crustacean that is a specialised marine wood borer. *S. annandalei* prefers mesohaline conditions (citations in Menon et al. 2000).

Common name:
Isopod.

Distribution:
Found in two of the 18 IUCN bioregions (see Figure 2).

Native: Central Indian Ocean.

Introduced: South Atlantic.

Larval period:
No information available.

Temperature tolerance:
Inferred: 20.9 °C to 32.4 °C.
Physiological: No information available.

Inoculation likelihood: LOW

Biofouling association rank – LOW

This species may bore into wooden boats (Sanagoudra & Neelakanton 2008).

Transport pressure rank – VERY LOW

Australian trade with the IUCN bioregions where *S. annandalei* is found represents 8.0% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 10.1% representing a very low likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – EXTREME

S. annandalei is a prolific wood borer and causes biodeterioration of mangroves (Venkatakrishnan & Balakrishnan Nair 1973).

Economic impacts – MODERATE

S. annandalei can cause biodeterioration of underwater timber construction, including marine structures and fishing craft (Sanagoudra & Neelakanton 2008).

Social/cultural impacts – NEGLIGIBLE

No information available.

Human health impacts – NEGLIGIBLE

No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **very low**) by consequence for each value category (i.e. **extreme, moderate, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	Moderate	Low	Low

Sylon hippolytes

Sylon hippolytes is a parasitic castrating barnacle, affecting a wide range of Caridean shrimp species throughout the coastal areas of the North Pacific. Its externa, the portion of the barnacle external to the host, can reach 1–1.5cm in diameter, usually underneath the abdomen.

Common name:
Parasitic barnacle.

Distribution:
Found in four of the 18 IUCN bioregions (see Figure 2).

Native: North West Pacific.

Introduced: Wider Caribbean Sea, Central Indian Ocean and East Asian Seas.

Larval period:
Larvae are discharged as cyprids. The period of time that cyprids spend in the plankton is unknown.

Temperature tolerance:
Inferred: -2.9 °C to 32.7 °C.
Physiological: Unknown.

Inoculation likelihood: MODERATE

Biofouling association rank – LOW
S. hippolytes is not a sessile or sedentary species, but is associated with secondary mobile species found in biofouling assemblages, including those organisms common in sea-chests of vessels (Coutts & Dodgshun 2007).

Transport pressure rank – MODERATE
Australian trade with the IUCN bioregions where *S. hippolytes* is found represents 58.1% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 73.4% representing a **moderate** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – NEGLIGIBLE
S. hippolytes is a parasitic castrator infecting at least 21 Caridean shrimp species. This species can cause a stunting of growth and alteration of sexual characteristics, with potential to sterilise males (Bower & Boutillier 1990; Lützen 1981). It usually occurs in a small percentage of wild populations (<5%).

Economic impacts – HIGH
S. hippolytes affects several species of commercial interest, including wild and aquaculture-farmed stocks (see Bower & Boutillier 1990). Infected prawns usually die when the parasite has completed its life cycle. Prawns that survive infection often exhibit brown or black scars, making them less desirable for market.

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **moderate**) by consequence for each value category (i.e. **negligible, high, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Low	High	Low	Low

Corethron criophilum

Corethron criophilum is a non-toxic cold water diatom.

Common name:
Diatom.

Distribution:
Found in one of the 18 IUCN bioregions (see Figure 2). New Zealand—considered to be cryptogenic as native region unknown.

Larval period:
Planktonic species.

Temperature tolerance:
Inferred: -2.85 ˚C to 31.7 °C. **Physiological:** Maximum is 6 ˚C to 9 °C, but minimum is unknown. Maximum growth occurs between 3 °C and 5 °C (Fiala & Oriol 1990).

Inoculation likelihood: EXTREMELY LOW

Biofouling association rank – NEGLIGIBLE

Planktonic species for entire life cycle; occurrence in biofouling assemblages is not recorded.

Transport pressure rank – EXTREMELY LOW

Australian trade with the IUCN bioregions where *C. criophilum* is found represents 7.0% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 8.4% representing an **extremely low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE

This species is one of the best competitors in cold-water phytoplankton communities for nitrate (Sommer 1991).

Economic impacts – HIGH

C. criophilum blooms can cause mortality of farmed coho salmon (Speare et al. 1989). The spines of *C. criophilum* cause the epithelium of the gills of fish to become physically irritated, which forms lesions and produces excessive mucus that leads to asphyxiation (Speare et al. 1989).

Social/cultural impacts – NEGLIGIBLE

No information available.

Human health impacts – NEGLIGIBLE

No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **extremely low**) by consequence for each value category (i.e. **moderate, high, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Low	Moderate	Very low	Very low

Avrainvillea amadelpha

Avrainvillea amadelpha is a green macroalgae which is most abundant in shallow, sandy habitats with low water motion. *A. amadelpha* forms dense clumps often covered with silt/sand and can also grow on rock or coral rubble (Hawaiian Biological Society [HBS] 2009). Its success as an invader has been attributed to its lack of predators and rapid growth rate (HBS 2009).

Common name:
Leather mudweed.

Distribution:
Found in four of the 18 IUCN bioregions (see Figure 2).

Native: Central Indian Ocean.

Introduced: East Africa, East Asian Seas and South Pacific.

Larval period
No information available.

Temperature tolerance:
Inferred: 14.6 °C to 35.3 °C.
Physiological: No information available.

Inoculation likelihood: LOW

Biofouling association rank – LOW

This species is able to attach and grow on hard substrates such as rock or coral rubble (HBS 2009).

Transport pressure rank – LOW

Australian trade with the IUCN bioregions where *A. amadelpha* is found represents 28.5% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 36.2% representing a low likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE

In Hawaii where it was recently introduced, *A. amadelpha* has out-competed native macrophytes, resulting in the reduction of native seagrass beds (University of Hawaii 2001). The closely packed blades of *A. amadelpha* trap sediments and provide habitat for filter feeders such as worms and molluscs. Trapped sediments eventually create a layer of mud, thus changing the nature of the substrate. *A. amadelpha* also decreases the heterogeneity of rocky reefs by covering holes and cracks, thus affecting recruitment of other species (HBS 2009).

Economic impacts – LOW

A. amadelpha decreases the heterogeneity of reef substrate by covering holes and cracks, which in turn may affect recruitment rates of species of commercial interest, such as octopus, lobsters and aquarium fisheries (HBS 2009). Loss of seagrass habitat may also impact on commercial and recreational fisheries (University of Hawaii 2010).

Social/cultural impacts – NEGLIGIBLE

No information available.

Human health impacts – NEGLIGIBLE

No information available.

Risks:

Multiplying the inoculation likelihood (i.e. low) by consequence for each value category (i.e. moderate, low, negligible, negligible) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Moderate	Low	Low

APPENDIX F
Species datasheet

Codium fragile atlanticum

Codium fragile atlanticum is a siphonous green seaweed. There are reportedly two subspecies found in Britain (*C. f. atlanticum and C. f. tomentosoides*), but as they are only distinguishable microscopically, there is much uncertainty as to when they were introduced and how they have spread (Joint Nature Conservation Committee [JNCC] undated; Guiry 2008). A third subspecies, *C. f. scandinavicum*, was introduced to Denmark and Norway from Asiatic coasts of the Pacific (JNCC undated). There has been much debate about how many distinct subspecies of *C. fragile* exist and which ones have invasive tendencies (Provan et al. 2008). Recent genetic studies have shown that in Britain, *C. f. atlanticum* is probably native; and *C. f. tomentosoides*, whilst introduced and invasive, is synonymous with *C. f. atlanticum* (Provan et al. 2008). Furthermore, the small genotypic variation reported, and the large phenotypic variation described, makes the described subspecies and varieties unsustainable. Therefore, for all practical purposes, it may be best to recognise one variable species of *C. fragile* (Guiry 2008). The Global Invasive Species Database states that *C. f. tomentosoides*: has been introduced around the world through shellfish aquaculture, recreational boating and transport on vessel hulls; and it fouls shellfish beds, accumulates and rots on beaches, and alters benthic communities and habitats (Invasive Species Specialists Group [ISSG] 2005b).

Common name:
Green sea fingers.

Distribution:
Found in three of the 18 IUCN bioregions (see Figure 2).

Native: North West Pacific (JNCC undated; Eno et al. 1997).

Introduced: North East Atlantic and West Africa for *C. f. atlanticum* (JNCC undated; Eno et al. 1997).

Larval period:
No information available.

Temperature tolerance:
Inferred: -2.9 °C to 31.5 °C.
Physiological: No information available.

Inoculation likelihood: LOW

Biofouling association rank – VERY LOW
C. f. atlanticum was intentionally introduced to Ireland with shellfish and may have spread around Britain through rafting or floating (Eno et al. 1997).

Transport pressure rank – MODERATE
Australian trade with the IUCN bioregions where *C. f. atlanticum* is found represents 40.7% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 51% representing a moderate likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
In Britain, *C. f. atlanticum* displaces the native species *C. tomentosum* (Farnham, cited in Eno et al. 1997).

Economic impacts – NEGLIGIBLE
No information available.

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. low) by consequence for each value category (i.e. moderate, negligible, negligible, negligible) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Low	Low	Low

Ulva pertusa

Ulva pertusa is a thin, green macroalgae that grows between the surface and 1 m depth on rocky substrates and hard structures (Verlaque et al. 2002). This species tolerates a wide range of salinities from marine conditions to salinities as low as 17–18 ppt, but is most common in coastal lagoons.

Common name:
Sea lettuce.

Distribution:
Found in two of the 18 IUCN bioregions (see Figure 2).

Native: North West Pacific.

Introduced: Mediterranean.

Larval period:
Information unavailable.

Temperature tolerance:
Inferred: -2.9 °C to 32.4 °C.
Physiological: Exact limits are unknown. Growth rate is highest at low temperatures, i.e. 15 °C (citations in Verlaque et al. 2002). On the Izu Peninsula, the species' optimum temperature for photosynthesis is 25 °C to 30 °C (citations in Verlaque et al. 2002). In the Thau Lagoon, *U. pertusa* is able to survive temperatures between 4 °C and 27 °C.

Inoculation likelihood: MODERATE

Biofouling association rank – HIGH

This is a biofouling species that grows on hard structures (Verlaque et al. 2002).

Transport pressure rank – LOW

Australian trade with the IUCN bioregions where *U. pertusa* is found represents 36.9% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 46.1% representing a **low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE

At certain times of the year, with the addition of nutrients to its habitat, *U. pertusa* forms dense blooms in inner bays of Japan and Korea, termed 'green tides' (Yabe et al. 2009). These blooms can affect seagrass beds mainly through shading (citations in Yabe et al. 2009). Decomposing *U. pertusa* typically wash up on beaches, resulting in decreased infaunal abundance and diversity (citations in Yabe et al. 2009).

Economic impacts – MODERATE

Washed up decomposing *Ulva* spp. can cause major economic impacts to tourism, as well as the costs involved with clean up activities (Charlier et al. 2007).

Social/cultural impacts – MODERATE

Washed up decomposing *Ulva* spp. produce noxious odours, which prevent people from utilising the waterfront areas (citations in Yabe et al. 2009).

Human health impacts – NEGLIGIBLE

The noxious odours produced by the decomposing *Ulva* spp. have the potential to cause damage to human health (Charlier et al. 2007).

Risks:

Multiplying the inoculation likelihood (i.e. **moderate**) by consequence for each value category (i.e. **moderate, moderate, moderate, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	High	High	Low

APPENDIX F
Species datasheet

Didemnum vexillum

Didemnum vexillum is an aggressive and rapidly spreading colonial ascidian (Bullard et al. 2007; Coutts & Forrest 2007). Colonies exhibit a wide range of morphological variation and can be pinkish, tan, or pale orange in colour (Valentine 2009). *D. vexillum* colonies can be long and rope-like (up to about 1 m in length) or can form extensive encrusting mats and can grow on a wide variety of hard substrata (Valentine 2009). Growth form appears to be related to habitat type, current velocities and space availability, as rope-like forms are common in low energy habitats, whereas mat-like colonies are common where tidal flows are strong (Valentine 2009). *D. vexillum* has been observed in nearshore and offshore sites and can grow at depths ranging from < 1 m to at least 81 m (Bullard et al. 2007).

Common names:
Colonial sea squirt, drooping sea squirt, ascidian, colonial tunicate.

Distribution:
Found in five of the 18 IUCN bioregions (see Figure 2).

Native: There is some uncertainty surrounding its native range, but recent genetic analysis suggests *D. vexillum* may be native to the North West Pacific bioregion (Japan; Lambert 2009).

Introduced: North West Atlantic (Bullard et al. 2007), North East Atlantic (Valentine 2009), North East Pacific (Daniel & Therriault 2007) and New Zealand (Kott 2009).

Larval period:
D. vexillum has pelagic larvae with a short larval period, generally less than one day (Osman & Whitlatch 2007). Fragments of *D. vexillum* colonies can also reattach and grow, facilitating spread to new locations (Valentine et al. 2009).

Temperature tolerance
Inferred: -2.9 °C to 32.4 °C.
Physiological: -2 °C to > 24 °C.

Inoculation likelihood: HIGH

Biofouling association rank – HIGH
D. vexillum readily fouls boat hulls, aquaculture structures and cultured shellfish (Coutts & Forrest 2007). Consequently, human-mediated transport via biofouling is the most important vector for long-distance dispersal (Svane & Young 1991; Osman & Whitlatch 2007).

Transport pressure rank – MODERATE
Australian trade with the IUCN bioregions where *D. vexillum* is found represents 50.5% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 62.4% representing a **moderate** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – HIGH
D. vexillum commonly overgrows other ascidian species (both colonial and solitary) as well as sponges, macroalgae, hydroids, anemones, bryozoans, scallops, mussels, polychaetes and crustaceans that have completed their terminal moult (Bullard et al. 2007).

Economic impacts – MODERATE
D. vexillum is considered a threat to aquaculture industries because of its demonstrated invasiveness and ability to over-settle and smother mussels (Coutts & Forrest 2007). Recent experimental studies have shown that widespread colonisation of substrata by *D. vexillum* could affect scallop fisheries, lowering recruitment through reduction of the area of quality habitats available for settlement (Morris et al. 2009). In addition, the Canadian aquaculture industry has reported that heavy infestations of non-indigenous ascidians result in increased handling and processing costs. Offshore fisheries may also suffer where high densities of *D. vexillum* may alter the access of commercially important fish species to critical spawning grounds, prey items and refugia (Daly & Scavia 2008).

Social/cultural impacts – VERY LOW
Large infestations of *D. vexillum* have the potential to causes loss of aesthetic value to a region, including loss of recreational value.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **moderate**) by consequence for each value category (i.e. **high, moderate, very low, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Extreme	High	Moderate	Low

Pseudochattonella farcimen (previously Chattonella aff. verruculosa)

*Pseudochattonella farcime*n is a cold water heterokont phytoflagellate. This is a new species based on a description of material from Skagerack sampled in 2001 (Eikrem et al 2009). The species is planktonic and is present in fjords, open water and open coastal area in the North Sea, Skagerrak and Kattegat (Naustvoll 2006).

Common name:
Raphidophyte.

Distribution:
Found in one of the 18 IUCN bioregions (Figure 2). North East Atlantic—where it is considered to be cryptogenic as its native region is unknown.

Larval period:
As this is a 'new' species, there is limited information available. The life history characteristics of *P. farcimen* are presently uncertain. Some preliminary experiments indicate that the species may form resting stages (cysts) under certain conditions. However, it is uncertain if such resting stages are part of a sexual reproduction. Vegetative growth is by ordinary cell division (citations in Naustvoll 2006).

Temperature tolerance:
Inferred: -1.5 °C to 27 °C.
Physiological: *P. farcimen* is a cold water species with optimal growth between 2 °C and 10 °C (citations in Naustvoll 2006). All blooms have occurred when the water temperature was below 10 °C (Naustvoll 2006).

Inoculation likelihood: VERY LOW

Biofouling association rank – EXTREMELY LOW
No information available.

Transport pressure rank – EXTREMELY LOW
Australian trade with the IUCN bioregions where *P. farcimen* is found represents 5.3% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 5.9% representing an **extremely low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
From April to May 1998, *P. farcimen* formed a massive bloom in the North Sea and off the coasts of Germany, Denmark, Sweden and Norway, which reportedly caused mortality among wild fish stocks (Naustvoll 2006).

Economic impacts – HIGH
The 1998 bloom of *P. farcimen* killed 350 tonnes of farmed salmon (citations in Edvardsen et al. 2007). This species also formed a bloom in April and May 2000 in the German Bight and off the Danish Jutland coast (citations in Edvardsen et al. 2007). In 2001, *P. farcimen* again caused fish mortalities in Norway, and 1100 tonnes of reared salmon were killed (Edvardsen et al. 2007). During the 2001 bloom, toxin analyses of seawater containing high density of *P. farcimen* were performed (citations in Edvardsen et al. 2007). No known algal toxins were detected in this seawater. The mechanism behind the fish mortality is still unknown.

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **very low**) by consequence for each value category (i.e. **moderate, high, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Moderate	Very low	Very low

Chattonella antiqua

Chattonella antiqua is a harmful red tide-forming phytoplankton species.

Common name:
Raphidophyte.

Distribution:
Found in one of the 18 IUCN bioregions (see Figure 2), North West Pacific where it is considered to be cryptogenic as its native region is unknown.

Larval period:
Chattonella spp are dormant between autumn and spring, in the form of cells on the sea floor. Vegetative planktonic cells are then present in the water column for approximately four months (Imai & Itoh 1987).

Temperature tolerance:
Inferred: -2.9 °C to 31.5 °C.
Physiological: 15 °C to 32.5 °C for total growth range (citations in Mikhail 2007). Dormant period under low temperatures (11 °C) is required for maturation. Germination of dormant resting stages for *C. antiqua* requires a minimum of 12 °C and maximum of 25 °C. Germination is at a maximum at 22 °C (Imai & Itoh 1987).

Inoculation likelihood: VERY LOW

Biofouling association rank – EXTREMELY LOW
No information available.

Transport pressure rank – LOW
Australian trade with the IUCN bioregions where *C. antiqua* is found represents 32.1% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 40.6% representing a **low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
C. antiqua is one of the most noxious red tide phytoplankton species. Blooms of *C. antiqua* in Japan have caused massive mortality of fish, crabs and other marine organisms (Hosoi-Tanabe et al. 2006).

Economic impacts – HIGH
Blooms produced by *C. antiqua* have caused serious damage to the fishery industry in Japan (Hosoi-Tanabe et al. 2006), especially to farming of the yellowtail, with damage costs reaching US$30 million during the red tides of 1972 (citations in Nakamura et al. 1989).

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **very low**) by consequence for each value category (i.e. **moderate, high, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Moderate	Very low	Very low

Fucus evanescens

Fucus evanescens is perennial brown seaweed which can reach up to 40cm in length. It is a common and often dominant species in its native range, forming a belt in the lower littoral (citations in Wikstrom 2004). The species is monoecious and will self-fertilise and has a maximum life-span of two to three years.

In areas where it has been introduced, *F. evanescens* has primarily established itself at sites where there are no native macroalgae, or where such species are rare, e.g. in harbours and other environments affected by human disturbance. *F. evanescens* contains high concentrations of defence chemicals, which cause grazer species to avoid it (although some grazing does occur). These substances are also an effective defence against epiphytic organisms (Wikstrom & Kautsky 2004).

Common name:
None.

Distribution:
Found in five of the 18 IUCN bioregions (see Figure 2).

Native: Arctic and North West Atlantic.

Introduced: North East Atlantic, Baltic and North West Pacific.

Larval period:
Larval period unknown, however, seaweeds generally have a short planktonic duration and effective dispersal shadows in the order of metres (citations in Wikstrom 2004).

Temperature tolerance:
Inferred: -2.9 °C to 32.4 °C.
Physiological: Information unknown.

Inoculation likelihood: LOW

Biofouling association rank – LOW
The primarily occurrence of *F. evanescens* in harbours and marinas between 1966 and 1972 suggests that the main mechanism for long distance dispersal was transport of reproductive plants associated with boats or fishing equipment (Wikstrom 2004). Since *F. evanescens* is monoecious and will self-fertilise, one fertile plant is enough to found a new population.

Transport pressure rank – LOW
Australian trade with the IUCN bioregions where *F. evanescens* is found represents 39.3% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 48.8% representing a low likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
During the first 20 years following establishment, this species spread quickly in the Oslofjord and has become the most common fucoid (citations in Wikstrom 2004). The increase in *F. evanescens* coincided with a general decline in native fucoid species, which was probably due to eutrophication (citations in Wikstrom 2004). It is thought that disturbance to native seaweed populations has facilitated the establishment of this species (Wikstrom 2004). *F. evanescens* has been found to support less biomass and fewer species of epiphytes than the native species of *F. vesiculosus* in Sweden (Wikstrom & Kautsky 2004). This implies that the invasion of this species may alter biodiversity and productivity at higher trophic levels. Up until now, however, it does not appear to have encroached on the habitats of other macroalgae, but seems rather to establish itself in areas where no other seaweed is present (Wikstrom & Kautsky 2004). Since the invader does not appear to competitively exclude native seaweeds, the effect of the invasion on Swedish coastal ecosystems is probably small (Wikstrom 2004).

Economic impacts – NEGLIGIBLE
No information available.

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. low) by consequence for each value category (i.e. moderate, negligible, negligible, negligible) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Low	Low	Low

Sargassum muticum

Sargassum muticum is a large brown macroalga that can attain lengths of several metres in shallow, sheltered waters. It is found primarily in bays and estuaries, but can also persist on the open coast. *S. muticum* often forms dense, monospecific stands. It occupies most hard substrates, however, rarely settles on small rocks or cobble.

Common names:
Japanese seaweed, Japweed, wire weed, strangle weed.

Distribution:
Found in eight of the 18 IUCN bioregions (see Figure 2).

Native: North West Pacific.

Introduced: Arctic, Mediterranean, North West Atlantic, North East Atlantic, Baltic, East Asian Seas and North East Pacific.

Larval period:
Planktonic period less than 48 hours (Deysher & Norton 1982). However, long distance dispersal (up to 900 km) can also occur via mature plants or branches drifting in ocean currents (Davison 1996).

Temperature tolerance:
Inferred: -2.9 °C to 32.7 °C.
Physiological: -1.4 °C to 30 °C (Hales & Fletcher 1989).

Inoculation likelihood: HIGH

Biofouling association rank – HIGH
S. muticum is a sessile species, directly attached to the primary substrate and with demonstrable association with vessel biofouling.

Transport pressure rank – HIGH
Australian trade with the IUCN bioregions where *S. muticum* is found represents 67.4% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 83.5% representing a **high** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – HIGH
S. muticum is a large brown alga that forms dense mats that out-compete other macroalgae and invertebrates through shading, whipping and smothering (Britton-Simmons 2004; Britton-Simmons & Abbott 2008). *S. muticum* is inferred to impact on seagrass species (den Hartog 1997), an important and often protected nursery habitat.

Economic impacts – HIGH
S. muticum is a nuisance biofouling species–it fouls all structures placed in the water, including wharves, jetties, boats, buoys and other navigation aids. The species causes: physical obstructions to navigation; specifically of small vessels; clogging of water intake pipes of boats and industrial installations; and smothering and interference with aquaculture operations, specifically oysters and mussels (Critchley et al. 1986).

Social/cultural impacts – MODERATE
Large dense stands of *S. muticum* cause loss of aesthetic value to a region, including loss of recreational value (Critchley et al. 1986).

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **high**) by consequence for each value category (i.e. **high, high, moderate, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Extreme	Extreme	High	Low

Anadara demiri

Anadara demiri is a bivalve that typically lives buried within the sediment on muddy and sandy substrates. However, the species may also inhabit hard substrata (e.g. rocks, mollusc shells, artificial substrates), attaching by means of byssus threads (Morello et al. 2004). *A. demiri* is considered one of the 100 'worst invasive' alien species in the Mediterranean Sea (citations in Albano et al. 2009).

Common name:
Arc shell.

Distribution:
Found in two of the 18 IUCN bioregions (see Figure 2).

Native: Origin unknown (Albano et al. 2009).

Introduced: Mediterranean and Central Indian Ocean.

Larval period:
Information about the species' larval period is unknown, however, larvae of a closely related species, *A. broughtoni*, begin to settle 30 days after fertilisation.

Temperature tolerance:
Inferred: -1.2 ˚C to 29.7 °C.
Physiological: Unknown.

Inoculation likelihood: LOW

Biofouling association rank – LOW

A. demiri is thought to have been introduced into the Mediterranean Sea either as planktonic larvae carried in vessels' ballast water or as benthic stages associated with aquaculture transfers of bivalves (citations in Morello et al. 2004). However, as this species is able to attach to hard substrates via byssus threads, it can potentially attach to the hulls of vessels.

Transport pressure rank – VERY LOW

Australian trade with the IUCN bioregions where *A. demiri* is found represents 9.4% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 11.3% representing a very low likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – LOW

A. demiri possesses a number of traits that make it a strong competitor– especially with respect to autochthonous bivalves. *A. demiri* is able to withstand intense environmental pollution and is capable of attaching to all kinds of hard substrata by means of byssus threads (Morello et al. 2004). The species is a very rapid coloniser and quickly becomes dominant in certain areas (Morello et al. 2004).

Economic impacts – MODERATE

The establishment of *A. demiri* could result in a loss of habitat occupied by commercially important species, such as *Chamelea gallina* in Italy (Morello et al. 2004). Furthermore, *A. demiri* may impact aquaculture operations–*A. demiri* juveniles have been observed attached to ropes used for mussel culture (citations in Morello et al. 2004).

Social/cultural impacts – NEGLIGIBLE

No information available.

Human health impacts – NEGLIGIBLE

No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **low, moderate, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Moderate	Low	Low

Anomia nobilis

Anomia nobilis is a bivalve which superficially resembles true oysters. However, they differ in relation to their mode of attachment (i.e. a byssal plug passing through an opening in the right valve) and their delicate translucent shells (Eldredge & Smith 2001). *A. nobilis* individuals are commonly found piled one on top of the other in the biofouling community. They are a very common biofouling organism, typically found on pier pilings and floating docks in harbours. They are also found intertidally on the under surface of flat stones.

Common names:
Jingle shell, saddle oyster.

Distribution:
Found in five of the 18 IUCN bioregions (see Figure 2).

Native: Central Indian Ocean, Arabian Seas and East Asian Seas.

Introduced: South Pacific (Hawaii).

Larval period:
No information available.

Temperature tolerance:
Inferred: 17.6 ˚C to 32.7 °C.
Physiological: No information available.

Inoculation likelihood: MODERATE

Biofouling association rank – HIGH
Species thought to have been introduced to Hawaii most likely as biofouling on vessels' hulls (Eldredge & Smith 2001).

Transport pressure rank – LOW
Australian trade with the IUCN bioregions where *A. nobilis* is found represents 31.5% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 40.2% representing a **low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
The ecological impact of *A. nobilis* is largely unstudied, but observations suggest competition with other biofouling invertebrates for space (Eldredge & Smith 2001).

Economic impacts – NEGLIGIBLE
In Hawaii, where this species has been introduced, *A. nobilis* is a common biofouling organism found on hard structures such as floating docks and pier pilings. When abundant, it forms dense stacks that are difficult to remove (Eldredge & Smith 2001). The cleaning of this nuisance biofouling species may cause economic impacts.

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:
Multiplying the inoculation likelihood (i.e. **moderate**) by consequence for each value category (i.e. **moderate**, **negligible**, **negligible**, **negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	Low	Low	Low

Brachidontes variabilis (pharaonis)

Brachidontes variabilis is a small gregarious intertidal bivalve that is dark in colour and reaches 4cm in width. It is found attached to gravel and rocks, often in association with oysters. It also attaches to mangrove roots (Galil 2006).

Common name:
Variable mussel.

Distribution:
Found in three of the 18 IUCN bioregions (see Figure 2).

Native: East Asian Seas and Arabian Seas.

Introduced: Mediterranean.

Larval period:
Planktonic larvae period is unknown.

Temperature tolerance:
Inferred: - 1.2 ˚C to 35.3 °C.
Physiological: In the Mediterranean *B. variabilis* show wide temperature tolerances (9 °C to 31 °C), and occurs at salinities from 35 ppt to 53 ppt (Galil 2006).

Inoculation likelihood: MODERATE

Biofouling association rank – HIGH

B. variabilis has probably been spread by vessel biofouling in the Mediterranean (Dogan et al. 2007).

Transport pressure rank – LOW

Australian trade with the IUCN bioregions where *B. variabilis* is found represents 26.8% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 33.4% representing a **low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – HIGH

In the Mediterranean, *B. variabilis* locally displaces the native mytilid, *Mytilaster minimus*. *B. variabilis* interferes with recruitment of *M. minimus*, and detrimentally affects its survival and growth. Surveys have shown that *B. variabilis* populations in the Mediterranean now reach densities up to 300 specimens per square metre, while *M. minimus* is now only rarely encountered (Galil 2006).

Economic impacts – HIGH

B. variabilis is a common biofouling mussel species in cooling water systems of tropical coastal power stations (Rajagopal et al. 2005).

Social/cultural impacts – NEGLIGIBLE

No information available.

Human health impacts – NEGLIGIBLE

No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **moderate**) by consequence for each value category (i.e. **high, high, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	High	Low	Low

Corbicula fluminea

Corbicula fluminea is a freshwater clam which is usually less than 2.5cm in length, but can grow up to 6.5cm (Invasive Species Specialists Group [ISSG] 2005a). *C. fluminea* is found in lakes and streams with silt, mud, sand, and gravel substrates (Institute of Natural Resource Sustainability [INHS] 2010). *C. fluminea* can tolerate salinities of up to 13 ppt for short periods (Aguirre & Poss 2010). It feeds on plankton, requires high levels of dissolved oxygen and is intolerant of pollution (Balcom 1994). The clam is hermaphroditic and is able to self-fertilise, capable of releasing hundreds or even thousands of juveniles per day and up to 70 000 per year (Balcom 1994).

Common names:
Asian clam, Asiatic clam.

Distribution:
Found in four of the 18 IUCN bioregions (see Figure 2).

Native: North West Pacific.

Introduced: North West Atlantic, North East Atlantic and North East Pacific.

Larval period:
Larvae spawned late in spring and early summer can reach sexual maturity by the next autumn (citations in ISSG 2005a). The juveniles are weak swimmers and are usually found near the bottom of the water column.

Temperature tolerance:
Inferred: -2.9 ˚C to 32.4 °C.
Physiological: 2 ˚C to 30 °C (Balcom 1994). Spawning can continue all year-round in water temperatures higher than 16 °C (ISSG 2005a).

Inoculation likelihood: LOW

Biofouling association rank – VERY LOW
The source of introduction of *C. fluminea* to North America is unknown. It is suspected that this species was brought from China by immigrants as a food source and subsequently released (Balcom 1994). This species cannot tolerate open sea salinities, so it is unlikely to survive transit across marine waters.

Transport pressure rank – MODERATE
Australian trade with the IUCN bioregions where *C. fluminea* is found represents 43.6% of the nation’s total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 54.1% representing a **moderate** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – LOW
Ecologically, *C. fluminea* alters benthic substrates (citations in Foster et al. 2009) and can out-compete many native clam species for limited resources (citations in ISSG 2005a).

Economic impacts – HIGH
The introduction of *C. fluminea* into the United States has resulted in the clogging of water intake pipes, affecting power, water and other industries. Nuclear service water systems (for fire protection) are very vulnerable, jeopardising fire protection. In 1980, the costs of correcting this problem were estimated at US$1 billion annually. *C. fluminea* causes such problems because its juveniles are weak swimmers, and consequently, they are pushed to the bottom of the water column where intake pipes are usually placed. They are drawn inside the intakes, where they attach, breed and die. The intake pipes become clogged with live clams, empty shells and dead body tissues. Buoyant dead clams can also clog intake screens (ISSG 2005a).

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **low, high, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	High	Low	Low

Corbula (Potamocorbula) amurensis

Corbula amurensis is an infaunal bivalve that grows to around 2–3cm in length. It is usually white, tan or yellow, with no markings on the external valves. *C. amurensis* buries into sediments on the sea floor, exposing half to two-thirds of its shell above this sediment in order to feed (citations in Invasive Species Specialists Group [ISSG] 2005c). It occurs in a range of sediment types including mud, peat, clay and sand, but is most abundant on mixed mud-sand substrates (citations in ISSG 2005c). *C. amurensis* is tolerant of a wide range of environmental conditions and is found across a broad range of salinities, ranging from 0–35 ppt (Nicolini & Penry 2000). *C. amurensis* exists from tropical to cold temperate waters, mostly subtidally, but it has been found in the intertidal zone (citations in ISSG 2005c).

Common names:

Amur river clam, Amur river corbula, brackish-water corbula, Chinese clam.

Distribution:

Found in two of the 18 IUCN bioregions (see Figure 2).

Native: North West Pacific.

Introduced: North East Pacific.

Larval period:

Larvae settle 17 to 19 days after fertilisation (Nicolini & Penry 2000).

Temperature tolerance:

Inferred: -2.9 ˚C to 32.4 °C.
Physiological: 8 ˚C to 23 °C (Cohen 2005b).

Inoculation likelihood: LOW

Biofouling association rank – VERY LOW

The most likely vector for the introduction of *C. amurensis* to San Francisco Bay is via larvae in association with vessels' ballast water. The species does not attach directly to hard substrates, but has the potential to occur as biofouling in vessels' sea-chests.

Transport pressure rank – LOW

Australian trade with the IUCN bioregions where *C. amurensis* is found represents 37.1% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 46.8% representing a **low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – LOW

C. amurensis has the ability to form dense populations with densities exceeding 10 000 individuals per square metre in its invaded range in San Francisco Bay. Establishment of such dense populations causes changes to sediment structure (Carlton et al. 1990). The capacity of dense *C. amurensis* populations to filter large volumes of phytoplankton and bacterioplankton also has the potential to permanently depress primary productivity and biomass of these organisms (Werner & Hollibaugh 1993). Establishment of *C. amurensis* in San Francisco Bay has also been demonstrated to result in displacement of native benthic communities, which were presumably excluded by *C. amurensis*' consumption of their food or larvae (Nichols et al. 1990).

Economic impacts – VERY LOW

It is thought to be responsible for the collapse of some commercial fisheries in addition to the decline in the diversity and abundance of many benthic species in the area (ISSG 2005c).

Social/cultural impacts – VERY LOW

There may be negative impacts on birds and fish populations as a result from feeding on *C. amurensis* (Cohen 2005b), potentially impacting on aesthetic values.

Human health impacts – NEGLIGIBLE

No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **low, very low, very low, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Low	Low	Low

Crassostrea ariakensis

Crassostrea ariakensis is a dioecious (two sexes), commercially important oyster species reaching 12cm in size. It is found primarily in bays and estuaries, but can also survive on the open coast. It is currently the focus of debate in the Chesapeake Bay (United States) as an introduced replacement for the declining native oyster, *C. virginica.*

Common names:
Suminoe oyster, Asian oyster.

Distribution
Found in three of the 18 IUCN bioregions (see Figure 2).

Native: North West Pacific.

Introduced: North West Atlantic and North East Pacific.

Larval period:
21 days (North et al. 2006).

Temperature tolerance:
Inferred: -2.9 ˚C to 32.4 °C.
Physiological: No information available.

Inoculation likelihood: LOW

Biofouling association rank – LOW
C. ariakensis is a sessile species, attaching directly to primary substrate, but its association with vessel biofouling is assumed because the genus is a known biofouling species.

Transport pressure rank – LOW
Australian trade with the IUCN bioregions where *C. ariakensis* is found represents 38.3% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 48.2% representing a **low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – LOW
C. ariakensis is a filter feeding oyster, with gregarious settlement leading to the establishment of high densities, out-competing native species for space and potentially causing larval depletion through filter feeding. It can cause habitat alteration by forming biogenic reefs and is known to interbreed with other oyster species, causing introgression into native populations and the species may harbour disease.

Economic impacts – LOW
C. ariakensis can interbreed with other commercial oyster species, causing outbreeding depression. The species is known to be affected by several OIE-listed molluscan diseases.

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – HIGH
C. ariakensis has been demonstrated to bioaccumulate toxins (e.g. paralytic shellfish poisoning, diarrhetic shellfish poisoning) through filter feeding. As a consequence, human consumption of *C. ariakensis* during or immediately following a toxic algal bloom event could transmit the toxins in sufficient quantities to cause human illness.

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **low**, **low**, **negligible**, **high**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Moderate	Low	High

Crassostrea virginica

The oyster *Crassostrea virginica* has a thick oval shell and grows to about 10cm—15cm in length. This species favours estuaries and bays and can also grow in marine environments. *C. virginica* are found in shallow waters of tidal to subtidal depth and are able to withstand a wide range of temperatures. In the United States, *C. virginica* is a commercially important fisheries species.

Common names:
Eastern oyster, American oyster.

Distribution:
Found in seven of the 18 IUCN bioregions (see Figure 2).

Native: North West Atlantic, Wider Caribbean Sea and South Atlantic.

Introduced: North East Pacific, Baltic and South Pacific.

Larval period:
Larvae take approximately two to three weeks to settle onto a substrate (CASIP 2009).

Temperature tolerance:
Inferred: -2.9 ˚C to 32.4 °C.
Physiological: Adult oysters are eurythermal and can withstand a wide range of temperatures, including freezing temperatures (Osborne 1999). Northern oysters spawn at temperatures between 15.5 ˚C and 20 °C, while southern oysters spawn at temperatures above 20 °C (Wallace 2001).

Inoculation likelihood: MODERATE

Biofouling association rank – HIGH
Introduction of this oyster species to Hawaii was intentional, for commercial oyster fishery. First plantings were in 1866 in Pearl Harbor (Bishop Museum and University of Hawaii [BMUH] 2002).

Transport pressure rank – LOW
Australian trade with the IUCN bioregions where *C. virginica* is found represents 23.8% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 29.2% representing a **low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
The ecological impact of *C. virginica* in Hawaii remains unstudied. Before a die-off in the early 1970s, these oysters formed extensive dense beds in the estuarine areas of Pearl Harbor, which undoubtedly affected the native benthic communities there (BMUH 2002). *C. virginica* is a key structural component of estuaries, playing a major role in the function of estuary ecosystems (citations in Puglisi 2008).

Economic impacts – HIGH
A major problem caused by the oyster is nuisance biofouling, often to boats (Osborne 1999).

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – MODERATE
The human pathogen *Vibrio vulnificus* is found in the tissues of some populations of *C. virginica*. *Vibrio vulnificus* causes primary septicaemia in patients with weakened immune systems. The infection occurs when the oyster are eaten raw (citations in Puglisi 2008).

Risks:

Multiplying the inoculation likelihood (i.e. **moderate**) by consequence for each value category (i.e. **moderate**, **high**, **negligible**, **moderate**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	High	Low	High

Crepidula fornicata

Crepidula fornicata is a protandrous hermaphrodite mollusc–beginning life as a male, then changing sex and developing into a female. *C. fornicata* can grow to 5cm and is a filter feeder, occurring within sheltered coastal bays and estuaries and sometimes in deeper water. It attaches firmly to objects with its muscular foot. Individuals may attach to each other to form ‘chains’.

Common names:
Slipper limpet, Atlantic slipper limpet.

Distribution:
Found in seven of the 18 IUCN bioregions (Figure 2).

Native: North West Atlantic, Wider Caribbean Sea and South Atlantic.

Introduced: Mediterranean, North East Atlantic, North East Pacific and North West Pacific.

Larval period:
The planktotrophic larval duration is approximately three weeks (Minchin 2008).

Temperature tolerance:
Inferred: -2.85 °C to 31.8 °C.
Physiological: This species can survive light frosts and in temperatures up to ~30 °C (Minchin 2008).

Inoculation likelihood: MODERATE

Biofouling association rank – MODERATE
This species may be transported on vessels’ hulls and in ballast water in the pelagic larval phase (Joint Nature Conservation Committee [JNCC] 2002).

Transport pressure rank – MODERATE
Australian trade with the IUCN bioregions where *C. fornicata* is found represents 55.2% of the nation’s total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 68.1% representing a **moderate** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – HIGH
C. fornicata may occur at densities exceeding 1700 individuals per square metre attaining a wet biomass of 10 kg per square metre. High *C. fornicata* densities result in competition with endemic species in coastal regions. Their abundance can change sediments to mud deposits of faeces, pseudofaeces and shell drifts. Such accumulating sediments on maerl beds reduce diversity and abundance of living plants (JNCC 2002). Shells may also provide a refuge for predators.

Economic impacts – HIGH
C. fornicata is considered a pest on commercial oyster beds, competing for space and food, while depositing mud on them that renders the substratum unsuitable for the settlement of spat (Viard & Dupont 2005). *C. fornicata* causes reduced growth of commercial bivalves in some enclosed bays and also need to be removed before marketing oysters. This species also fouls artificial structures in port regions and may reduce recruitment of some commercially important fishes (Minchin 2008).

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **moderate**) by consequence in each value category (i.e. **high, high, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration:

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	High	Low	Low

Dreissena bugensis

Dreissena bugensis is a freshwater mussel that reaches a maximum size of 6cm. The embryos and larvae of *D. bugensis* are less tolerant of salinity than those of zebra mussels (*D. polymorpha*) and have upper salinity limits of about 5 ppt (citations in Cohen 2007). Cohen (2007) concluded that the limiting maximum salinity for zebra mussels was 4 ppt, although it would be less in waters with rapidly fluctuating salinities (estuaries). Juvenile and adult *D. bugensis* attach to hard surfaces using byssal threads and also have the ability to build up populations on soft substrates (Cohen 2007). *D. bugensis* individuals byssally attach to the shells of other mussels and can form thick mats several layers thick (Invasive Species Specialists Group [ISSG] 2006). *D. bugensis* was introduced to the Great Lake system following the introduction of the zebra mussel (*D. polymorpha*). *D. bugensis* has begun to replace the zebra mussel as the most dominant invasive *Dreissena* species and it is able to colonise at much deeper depths (ISSG 2006).

Common name:
Quagga mussel.

Distribution:
Found in three of the 18 IUCN bioregions (see Figure 2).

Native: Ponto-Caspian Basin (Cohen 2007, Benson et al. 2009) (Note that this is not IUCN bioregion).

Introduced: North West Atlantic (including the North American Great Lakes), North East Atlantic and Baltic (Benson et al. 2009).

Larval period:
D. bugensis spawn from spring to autumn and produce large numbers of planktonic larvae (veligers) that typically spend one to several weeks drifting in the water column before attachment (citations in Cohen 2007). Planktonic periods are longer at lower temperatures and veligers may remain in the plankton over winter (citations in Cohen 2007).

Temperature tolerance:
Inferred: -2.9 ˚C to 32.4 °C.
Physiological: Upper temperature limit may be as low as 25 °C, although there is evidence indicating that they can survive temperatures as high as 30 °C (citations in Cohen 2007). There is some evidence of spawning in Lake Erie in North America at temperatures as low as 4.8 °C (citations in Cohen 2007).

Inoculation likelihood: LOW

Biofouling association rank – HIGH
The introduction of *D. bugensis* to the Great Lakes appears to have been through ballast water discharge from transoceanic vessels that were carrying veligers, juveniles or adult mussels (Benson et al. 2009).

Transport pressure rank – EXTREMELY LOW
Australian trade with the IUCN bioregions where *D. bugensis* is found represents 7.0% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 7.9% representing an **extremely low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
D. bugensis are efficient filter feeders and can remove phytoplankton resources from the water column, potentially altering trophic dynamics (Cohen et al. 2007; Benson et al. 2009).

Economic impacts – HIGH
D. bugensis cause massive nuisance biofouling of submerged objects and water pipes (Cohen et al. 2007). They rapidly colonise hard surfaces causing serious economic problems–clogging water intake structures and causing massive biofouling on docks, breakwalls, buoys, boats and beaches (Benson et al. 2009).

Social/cultural impacts – LOW
Major detrimental impact on recreational boating due to biofouling (ISSG 2006).

Human health impacts – VERY LOW
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **moderate**, **high, low, very low**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	High	Moderate	Low

Dreissena polymorpha

Dreissena polymorpha (zebra mussel) is a freshwater mussel that reaches a maximum size of 5cm. Salinity tolerances reported for zebra mussels vary widely and may be dependent on both the rate of changes in salinity and water chemistry (Cohen 2007). The species' upper salinity limit appears to be about 10 ppt–zebra mussels were abundant throughout the Aral Sea at salinities of 10 ppt (citations in Cohen 2007). Cohen (2007) concluded that the limiting maximum salinity for zebra mussels was 6 ppt, although it would be less in waters with rapidly fluctuating salinities (estuaries). Juveniles and adults of the species attach to hard surfaces using byssal threads and also have the ability to build-up populations on soft substrates (Cohen 2007).

Common names:

Zebra mussel, European zebra mussel.

Distribution:

Found in three of the 18 IUCN bioregions (see Figure 2).

Native: Ponto-Caspian Basin (Cohen 2007).

Introduced: North West Atlantic including the North American Great Lakes in southern Canada and the United States (Cohen 2007), North East Atlantic and Baltic.

Larval period:

Larval duration is 10 to 90 days (Reed et al. 1998). Planktonic larvae (veligers) typically spend one to several weeks drifting in the water column before attachment (citations in Cohen 2007). Planktonic periods are longer at lower temperatures and veligers may remain in the plankton over winter (citations in Cohen 2007).

Temperature tolerance:

Inferred: -2.85 ˚C to 31.8 °C.
Physiological: *D. polymorpha* can tolerate water temperatures as low as 6 °C in winter, but summer water temperatures above 6 °C to 12 °C are needed to support adult growth (citations in Cohen 2007). In general, temperatures above 12 °C are needed for *D. polymorpha* spawning and it is considered that mean summer temperatures of 9 ˚C to 15 ˚C are the lower limiting temperatures for potential distribution (citations in Cohen 2007). The upper limit for *D. polymorpha* survival is thought to be approximately 30 °C (citations in Cohen 2007).

Inoculation likelihood: LOW

Biofouling association rank – HIGH

D. polymorpha is probably dispersed through human activities e.g. artificial waterways, vessels, fishing activities, amphibious planes and recreational equipment (Gulf States Marine Fisheries Commission [GSMFC] 2005). *D. polymorpha* may be naturally dispersed after being attached to aquatic plants that break off and move downstream, or to other organisms (e.g. mud stuck to birds or crayfish) (Cohen 2007). *D. polymorpha* cannot tolerate open sea salinities, so it is unlikely to survive voyages that involve transit across marine waters.

Transport pressure rank – EXTREMELY LOW

Australian trade with the IUCN bioregions where *D. polymorpha* is found represents 7.0% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 7.9% representing an **extremely low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – HIGH

In the Great Lakes in the United States, *D. polymorpha* can disrupt existing food webs by consuming phytoplankton and altering physical conditions (increased light levels). They may also threaten biodiversity via competition with native organisms (Cohen 1998).

Economic impacts – HIGH

In the Great Lakes, *D. polymorpha* have blocked pipes that deliver water to cities and factories, and cooling water to nuclear and fossil fuel-fired power plants. *D. polymorpha* cause massive nuisance biofouling to vessel and boat hulls, marine structures and navigational buoys (Cohen 1998).

Social/cultural impacts – MODERATE

D. polymorpha cover the beaches of the Great Lakes with sharp-edged shells and rotting mussel flesh (Cohen 1998).

Human health impacts – VERY LOW

There are indications that *D. polymorpha* promoted blooms of the toxic planktonic colonial cyanobacterium, *Microcystis aeruginosa* in Lake Huron through selection rejection in pseudofaeces (Vanderploeg et al. 2001). *Microcystis* spp. produce a potent class of hepatotoxins that can poison aquatic organisms, wildlife and humans (Carmichael, in Vanderploeg et al. 2001).

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **high, high, moderate, very low**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	High	Moderate	Low

Geukensia demissa

Geukensia demissa is a mussel with an olive-brown periostracum (thin, glossy tissue covering the shell) that generally grows to about 10cm in length (Cohen 2005a). It is mainly a subtidal species (on oyster reefs), but can be found in the intertidal zone in salt marshes (Cohen 2005a). *G. demissa* sometimes occurs above the mud surface attaching to pilings, concrete walls or rocks; and occasionally in the biofouling community on floating docks (Cohen 2005a).

Common names:

Ribbed mussel, ribbed horse mussel.

Distribution:

Found in two of the 18 IUCN bioregions (see Figure 2).

Native: North West Atlantic.

Introduced: North East Pacific.

Larval period:

The planktonic larvae are present in the water from early summer to early autumn (Cohen 2005a).

Temperature tolerance:

Inferred: -2.9 ˚C to 32.4 °C.
Physiological: In California, *G. demissa* has been collected in water temperatures of 13 ˚C to 22 °C and can tolerate short-term exposures to water temperatures up to 56 °C (Cohen 2005a).

Inoculation likelihood: VERY LOW

Biofouling association rank – LOW

On the Atlantic Coast, *G. demissa* frequently occurs on reefs dominated by the Virginia oyster (*Crassostrea virginica*). Its introduction to San Francisco Bay probably resulted from shipments of these oysters (Cohen 2005a). *G. demissa* may also have been transported from San Francisco Bay to other locations in California through hull biofouling (Cohen 2005a).

Transport pressure rank – EXTREMELY LOW

Australian trade with the IUCN bioregions where *G. demissa* is found represents 6.2% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 7.6% representing an **extremely low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – EXTREME

G. demissa can affect the cycling of nutrients in Atlantic salt marshes by removing a third of the particulate phosphorus from suspension and depositing it on the mud surface (Kuenzler 1961 in Cohen 2005a). In San Francisco Bay, *G. demissa* are consumed by the endangered California Clapper Rail (*Rallus longirostris obsoletus*), but the toes and probing beaks of Clapper Rails are frequently caught and clamped between the gaping shells of the mussel that protrude from the mud (de Groot 1927 in Cohen 2005a). Clapper Rails can lose their toes to ribbed mussels or have their beaks clamped shut and die of starvation, or chicks can be caught by mussels and drown by the incoming tide (Cohen 2005a). There are reports of nearly every Clapper Rail in San Francisco Bay missing one or more toes as well as reports of Clapper Rails with ribbed mussels clamped to their toes or bills (Cohen 2005a). In Newport Bay, California, United States, the Light-footed Clapper Rail (*R. longirostris levipes*) are also thought to lose their toes after being caught by *G. demissa* (Zembal & Fancher, cited in Cohen 2005a).

Economic impacts – NEGLIGIBLE

No information available.

Social/cultural impacts – NEGLIGIBLE

No information available.

Human health impacts – NEGLIGIBLE

No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **very low**) by consequence for each value category (i.e. **extreme**, **negligible**, **negligible**, **negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Very low	Very low	Very low

Limnoperna fortunei

Limnoperna fortunei is a dioecious (two sexes) bivalve, found primarily in lower salinities of estuaries and rivers, however, it is capable of persisting in higher salinities and is found in fully saline harbours (Morton 1973; Darrigan & de Drego 2000). *L. fortunei* is a filter feeder that attaches to a wide variety of hard substrates using byssal threads.

Common name:
Golden mussel.

Distribution:
Found in two of 18 the IUCN bioregions (see Figure 2).

Native: East Asian Seas.

Introduced: South Atlantic.

Larval period:
30 to 70 days (United States Army Corps of Engineers 2006).

Temperature tolerance:
Inferred: -2.9 ˚C to 32.7 °C.
Physiological: 8 ˚C to 35 °C (Ricciardi, 1998).

Inoculation likelihood: MODERATE

Biofouling association rank – MODERATE

L. fortunei is a sessile species that directly attaches to primary substrate and is known to be associated with biofouling.

Transport pressure rank – LOW

Australian trade with the IUCN bioregions where *L. fortunei* is found represents 21.7% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 27.3% representing a low likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE

L. fortunei has been demonstrated to bioaccumulate microcystin toxins, which cause mortalities in birds that prey on them. *L. fortunei* has been recorded at densities of up to 150 000 individuals per square metre and out-competes other species for space and food. Darrigan & de Drago (2000) identified the displacement of native gastropods in South America by *L. fortunei*.

Economic impacts – MODERATE

L. fortunei is a nuisance fouler of any structures placed in the water, including wharves, jetties, boats, buoys and other navigation aids. *L. fortunei* also has been inferred to reach sufficiently high densities to clog water intake systems (Ricciardi 1998).

Social/cultural impacts – NEGLIGIBLE

No information available.

Human health impacts – MODERATE

L. fortunei has been demonstrated to bioaccumulate microcystin toxins. As a consequence, human consumption of *L. fortunei* during or immediately following a toxic blue-green algal bloom event could transmit the toxins in sufficient quantities to cause human illness.

Risks:

Multiplying the inoculation likelihood (i.e. moderate) by consequence for each value category (i.e. moderate, moderate, negligible, moderate) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	High	Low	High

Mya arenaria

Mya arenaria is an infaunal bivalve that lives buried up to 30cm below the surface in sand, mud and clays, often in mixtures with coarse gravel (Cohen 2005c). *M. arenaria* typically occurs in bays and estuaries in the upper intertidal zone. It also occurs in the low intertidal and shallow subtidal zones, and is also occasionally reported from deeper water. *M. arenaria* adults are tolerant of low salinities (down to 5 ppt) and low oxygen conditions (survival observed in anoxic conditions after eight days) (Cohen 2005c).

Common names:
Soft-shell clam, sandgaper, steamer clam.

Distribution:
Found in seven of the 18 IUCN bioregions (see Figure 2).

Native: Arctic, North West Atlantic (eastern North America) and North East Pacific. *M. arenaria* has been reported as native to the North West Pacific (Korea and Japan), but this record is now thought to be *M. japonica*.

Introduced: Mediterranean, North East Atlantic, Baltic and North West Pacific.

Larval period:
Typically two to three weeks, but can be up to six weeks (Cohen 2005c).

Temperature tolerance:
Inferred: -2.9 ˚C to 32.4 °C.
Physiological: -2 ˚C to 28 °C.

Inoculation likelihood: VERY LOW

Biofouling association rank – VERY LOW
Historically, *M. arenaria* have been deliberately introduced in the past, but they are also thought to have been accidentally translocated in association with transfer of oysters. The species does not attach directly to hard substrates. It has the potential to occur as biofouling in vessels' sea-chests.

Transport pressure rank – VERY LOW
Australian trade with the IUCN bioregions where *M. arenaria* is found represents 17.1% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 20% representing a **very low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – VERY LOW
M. arenaria has the ability to reach high population densities, up to 1000 individuals per square metre, and 19th century workers reported that it replaced populations of the native bent-nosed clam *Macoma nasuta* (Cohen 2005c). *M. arenaria* has also been demonstrated to alter nutrient cycling in soft sediments (Hansen et al. 1996). Other ecological impacts of *M. arenaria* include benthic-pelagic interaction, bioaccumulation, community dominance and habitat change (Baltic Sea Alien Species Database 2007).

Economic impacts – VERY LOW
No information available.

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – HIGH
M. arenaria has been demonstrated to bioaccumulate toxins (e.g. paralytic shellfish poisoning, diarrhetic shellfish poisoning) through filter feeding (MacQuarrie & Bricelj 2008). As a consequence, human consumption of *M. arenaria* during or immediately following a toxic algal bloom event could transmit the toxins in sufficient quantities to cause human illness.

Risks:

Multiplying the inoculation likelihood (i.e. **very low**) by consequence for each value category (i.e. **very low**, **very low**, **negligible**, **high**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Low	Low	Very low	Moderate

Mytella charruana

Mytella charruana is a tropical bivalve whose native distribution extends from South and Central America northward through Mexico (Masterson 2007). *M. charruana* are usually less than 2cm in length, but can be larger than 4cm (The Nature Conservancy undated). Similar to other mussel species, it attaches to hard substrates such as oyster shells as well as man-made structures, e.g. water intake pipes, wood pilings, driftwood (Masterson 2007).

Common name:
Charru mussel.

Distribution:
Found in two of the 18 IUCN bioregions (see Figure 2).

Native: South Atlantic.

Introduced: Wider Caribbean Sea (Florida, Benson 2008; Georgia, Masterson 2007).

Larval period:
No information available.

Temperature tolerance:
Inferred: -2.9 ˚C to 31.5 °C, although stated to be 'tropical'.
Physiological: The die-off in mussels found at the Jacksonville, Florida, power plant is thought to have been due to colder winter temperatures (Boudreaux & Walters, cited in Masterson 2007).

Inoculation likelihood: VERY LOW

Biofouling association rank – LOW

Probably introduced to North America through ballast water (Benson 2008).

Transport pressure rank – EXTREMELY LOW

Australian trade with the IUCN bioregions where *M. charruana* is found represents 6.7% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 8.5% representing an extremely low likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE

M. charruana has the potential to greatly increase and compete with native organisms (The Nature Conservancy undated). *M. charruana* individuals in Mosquito Lagoon (near the Kennedy Space Center, Florida) were observed on a reef where they could compete with native organisms for food and habitat (Benson 2008).

Economic impacts – HIGH

M. charruana has caused nuisance biofouling of intake pipe filters at a power plant in Jacksonville, Florida, showing its potential to decrease efficiency and increase costs at industrial plants and power utilities (Benson 2008). It also has the potential to compete with commercially important native oysters (The Nature Conservancy undated).

Social/cultural impacts – NEGLIGIBLE

No information available.

Human health impacts – NEGLIGIBLE

No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **very low**) by consequence for each value category (i.e. **moderate, high, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Moderate	Very low	Very low

Mytilopsis leucophaeata

Mytilopsis leucophaeata is a dioecious (two sexes) bivalve. It is found primarily in bays and estuaries, but capable of withstanding a wide range of salinities, resulting in its presence in open coastal waters and waters <1 ppt (Rajagopal et al. 2003). *M. leucophaeata* settles on any hard substrate placed in the water.

Common names:
Dark false mussel, Conrad's false mussel.

Distribution:
Found in five of the 18 IUCN bioregions (see Figure 2).

Native: North West Atlantic and Wider Caribbean Sea.

Introduced: North East Atlantic, Baltic and North West Pacific.

Larval period:
Information about larval duration for this species was not available, but for a closely related species–*Dreissena polymorpha*–the period is 10 to 90 days (Reed et al. 1998).

Temperature tolerance:
Inferred: -2.9 ˚C to 31.8 °C.
Physiological: 5 ˚C to 35 °C (Rajagopal et al 2002; Rajagopal et al 2005).

Inoculation likelihood: HIGH

Biofouling association rank – HIGH
M. leucophaeata is a sedentary species with a direct association with biofouling.

Transport pressure rank – MODERATE
Australian trade with the IUCN bioregions where *M. leucophaeata* is found represents 42.4% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 52.6% representing a **moderate** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
M. leucophaeata competes with other fouling organisms and causes competitive displacement, reaching densities of up to 28 000 individuals per square metre (Bergstrom 2004).

Economic impacts – HIGH
M. leucophaeata is a nuisance biofouling species, fouling all structures placed in the water including wharves, jetties, boats, buoys and other navigation aids (Bergstrom 2004; Smith & Boss 1996). Similarly, *M. leucophaeata* is inferred to cause clogging of water intake systems (Rajagopal et al. 2003).

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **high**) by consequence for each value category (i.e. **moderate**, **high**, **negligible**, **negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	Extreme	Low	Low

APPENDIX F
Species datasheet

Mytilopsis sallei

Mytilopsis sallei is a small mussel that grows to an average size of 2.5cm (National Introduced Marine Pests Information System [NIMPIS] 2002c). It is a colonial surface dweller of sheltered, shallow waters and has high fecundity, rapid growth and a fast maturity rate (NIMPIS 2002c). During their lifespan, *M. sallei* individuals change sex so that a proportion of mussels in any population are hermaphrodites (NIMPIS 2002c). Spawning appears to be triggered by salinity changes, and eggs and sperm are spawned into the water column where external fertilisation takes place (NIMPIS 2002c). In its introduced habitat, *M. sallei* is found at a range of salinities (0–27 ppt) (NIMPIS 2002c). In 1999, this species was found on three marinas and on vessels in Darwin Harbour. Following a rapid response to the incursion, the species was subsequently eradicated (Coles & Eldredge 2002; Bax et al. 2002).

Common names:
Black striped mussel.

Distribution:
Found in eight (eradicated from one) of the 18 IUCN bioregions (see Figure 2).

Native: North West Atlantic, Wider Caribbean Sea and South Atlantic.

Introduced: Central Indian Ocean (India, NIMPIS 2002c), East Asian Seas (Singapore, Sin et al. 1991; Malaysia, Tan & Norton 2006), South Pacific, North West Pacific (Japan, Taiwan, Hong Kong; NIMPIS 2002c, Bax et al. 2002), and Australia (introduced to Darwin Harbour and subsequently eradicated).

Larval period:
Pelagic larvae develop within a day of fertilisation and then settle within a few days (NIMPIS 2002c). *M. sallei* is extremely prolific and fecund (Commonwealth Scientific and Industrial Research Organisation 2001).

Temperature tolerance:
Inferred: -2.9 ˚C to 32.7 °C.
Physiological: In its introduced habitat, *M. sallei* is found at a range of temperatures from 10 ˚C to 30 °C (NIMPIS 2002c).

Inoculation likelihood: HIGH

Biofouling association rank – HIGH
M. sallei was found in Darwin Harbour in 1999 and believed to have entered marinas as biofouling on the hulls of yachts (Coles & Eldredge 2002). In 2000, it was found on hulls of two Indonesian fishing boats quarantined in Darwin Harbour (Willan et al. 2000). *M. sallei* is thought to have been introduced to Hong Kong via a Vietnamese refugee boat (Huang & Morton 1983).

Transport pressure rank – HIGH
Australian trade with the IUCN bioregions where *M. sallei* is found represents 74.8% of the nation’s Australia’s total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 94.1% representing a **high** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
M. sallei forms dense monospecific aggregations that exclude most other species, leading to decreased biodiversity (NIMPIS 2002c). The discovery of this species in Darwin Harbour was considered a threat to the environment (Bax et al. 2002).

Economic impacts – HIGH
M. sallei causes massive nuisance biofouling on wharves and marinas, seawater systems (pumping stations, vessel ballast and cooling systems), marine farms (NIMPIS 2002c) and vessel hulls (Huang & Morton 1983). When discovered in Darwin Harbour, *M. sallei* was considered a threat to water-dependent marine infrastructure around northern Australia and to the local A$40 million pearl fishery industry (Bax et al. 2002). In Singapore, this mussel has formed a broad, extensive, densely populated strip on the vertical and sloping concrete walls of monsoon canals that reach up to several kilometres inland from the sea (Tan & Morton 2006).

Social/cultural impacts – LOW
Biofouling can cause losses to public or tourist amenities. Vessel biofouling reduces efficiency and can impact on transport systems.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **high**) by consequence for each value category (i.e. **moderate, high, low, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	Extreme	Moderate	Low

Perna perna

Perna perna is a dioecious (two sexes), mytilid bivalve, reaching 12cm in size. It is found in bays and estuaries as well as the open coast. *P. perna* creates extensive biofouling, settling on a variety of substrates including exposed rocky intertidal and protected man-made structures (Hicks et al. 2001). *P. perna* has a wide salinity tolerance, but has a low freeze resistance (Hicks & McMahon 2002) and is found in tropical to sub-temperate waters.

Common name:
Brown mussel.

Distribution:
Found in seven of the 18 IUCN bioregions (see Figure 2).

Native: This remains equivocal, however, is believed to be both sides of the South Atlantic, representing IUCN bioregions of the South Atlantic and West Africa.

Introduced: Mediterranean, Wider Caribbean Sea, Central Indian Ocean, Arabian Seas, and East Africa. Recently, *P. perna* was detected in New Zealand.

Larval period:
Larval period is 15 to 20 days, but settlement can be delayed for up to three months when food availability and temperatures are low, as has been shown for other species of the *Mytilidae* family (Bayne 1965).

Temperature tolerance:
Inferred: -1.2 ˚C to 35.3 °C.
Physiological: 10 ˚C to 30 °C (Romero & Moreira 1980; Siddall 1978). Metamorphosis of larvae is limited to temperatures between 18 °C and 30 °C (Siddall 1978). Temperature tolerance for veliger stages is 10 °C to 30 °C (Romero & Moreira 1980).

Inoculation likelihood: MODERATE

Biofouling association rank – HIGH
P. perna is a sedentary species, with known associations with vessel biofouling, and the genus has been identified in sea-chests of vessels (Coutts & Dodgshun 2007).

Transport pressure rank – LOW
Australian trade with the IUCN bioregions where *P. perna* is found represents 30.9% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 38.4% representing a **low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – HIGH
P. perna is a large and successful biofouling species which can out-compete other native epibenthic species.

Economic impacts – LOW
P. perna is a nuisance biofouling species, fouling all structures placed in the water including wharves, jetties, boats, buoys and other navigation aids. In extreme situations, the species can cause navigational buoys to submerge due to high biomass (Hicks & Tunnell 1993).

Social/cultural impacts – MODERATE
Potential for *P. perna* to impact on aesthetic and recreational values.

Human health impacts – EXTREME
P. perna has been demonstrated to bioaccumulate toxins (e.g. paralytic shellfish poisoning) through filter feeding (Barbera-Sanchez et al. 2004). As a consequence, human consumption of *P. perna* during or immediately following a toxic algal bloom event could transmit the toxins in sufficient quantities to cause human illness.

Risks:

Multiplying the inoculation likelihood (i.e. **moderate**) by consequence for each value category (i.e. **high, low, moderate, extreme**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	Moderate	High	Extreme

Perna viridis

Perna viridis is a dioecious (two sexes), commercially important bivalve species in its native region of the East Asian Seas, reaching >16cm in size. It is found primarily in bays and estuaries, but can also survive on the open coast. It can withstand a wide range of salinities and reaches high densities—up to 35 000 individuals per square metre (National Introduced Marine Pests Information System 2002).

Common name:
Asian green mussel.

Distribution:
Found in seven of the 18 IUCN bioregions (see Figure 2).

Native: East Asian Seas and North West Pacific.

Introduced: Wider Caribbean Sea, South Atlantic, Central Indian Ocean, Arabian Seas and South Pacific

Note that in August 2001, *P. viridis* was detected in Trinity Inlet, Cairns, Australia, and subsequent removal and evaluation has not detected an established population (Hayes et al. 2005).

Larval period:
26 to 33 days (Rajagopal et al. 1998).

Temperature tolerance:
Inferred: -2.9 °C to 35.3 °C.
Physiological: 7 °C to 37.5 °C (Segnini de Bravo et al. 1998).

Inoculation likelihood: HIGH

Biofouling association rank – HIGH
P. viridis is a sedentary species, with known associations with vessel biofouling. The genus has been identified in sea-chests of vessels (Coutts & Dodgshun 2007). It was detected as vessel fouling in Trinity Inlet, Cairns, Australia, and was subsequently removed (Hayes et al. 2005).

Transport pressure rank – HIGH
Australian trade with the IUCN bioregions where *P. viridis* is found represents 77.3% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 97.6% representing a **high** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
P. viridis is a large and successful biofouling species which can out-compete other native epibenthic species causing changes in community structure and trophic interactions.

Economic impacts – LOW
P. viridis is a nuisance biofouling species, fouling all structures placed in the water including wharves, jetties, boats, mariculture equipments, buoys and other navigation aids. In India, it causes significant harm, clogging water intakes for industrial cooling systems (Rajagopal et al. 1996, 1998).

Social/cultural impacts – MODERATE
Potential for *P. viridis* to impact on aesthetic and recreational values.

Human health impacts – EXTREME
P. viridis has been demonstrated to bioaccumulate toxins (e.g. paralytic shellfish poisoning, amnesic shellfish poisoning, diarrhetic shellfish poisoning and hepatitis A virus) through filter feeding (Ammons et al. 2001; Lee et al. 1997). As a consequence, human consumption of *P. viridis* during or immediately following a toxic algal bloom event could transmit the toxins in sufficient quantities to cause human illness. Human deaths have been recorded.

Risks:

Multiplying the inoculation likelihood (i.e. **high**) by consequence for each value category (i.e. **moderate, low, moderate, extreme**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	Moderate	High	Extreme

Rapana venosa (thomasiana)

Rapana venosa originated in the Japanese Sea. This species has been introduced to the Black Sea (first recorded in 1946) and Azov Sea where it has become widespread, except in low salinity areas (Uyan & Aral 2003). Due to the demand for *Rapana* spp. meat on the international market, *R. venosa* has become an important economic species in the Black Sea (Uyan & Aral 2003). This species is an active carnivore, preferring habitats occupied by both bivalve and crustacean species and can be found in soft substratum as well as rocky areas (Sahin et al. 2009). *R. venosa* occurs in depths of 1–90 m in the Black Sea and seasonally migrates from shallow waters (< 15 m) in the summer to deeper waters in the winter (> 15 m) (Sahin et al. 2009).

Common names:
Rapa whelk, Japanese sea snail, veined rapa whelk.

Distribution:
Found in five of the 18 IUCN bioregions (see Figure 2).

Native: North West Pacific (Japanese Sea; Uyan & Aral 2003).

Introduced: Mediterranean (Black Sea and Azov Sea, Uyan & Aral 2003; Aegean and Adriatic Seas, Sahin et al. 2009), North West Atlantic, North East Atlantic and South Atlantic.

Larval period:
Based on a study in the Black Sea, after the completion of the early larval development stage in the egg capsule, the larvae hatched from the capsule as a veliger on day 20 (Uyan & Aral 2003). The larvae were then pelagic for the following five days and settled to the bottom on day 25 (Uyan & Aral 2003).

Temperature tolerance:
Inferred: -2.9 °C to 31.5 °C.
Physiological: Information unknown.

Inoculation likelihood: LOW

Biofouling association rank – VERY LOW
R. venosa is thought to have been introduced into the Black Sea by a vessel carrying its eggs attached to the hull (Uyan & Aral 2003). *R. venosa* is also possibly transported through ballast water (citations in Sahin et al. 2009).

Transport pressure rank – MODERATE
Australian trade with the IUCN bioregions where *R. venosa* is found represents 46.9% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 57.7% representing a **moderate** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – HIGH
R. venosa is a carnivorous gastropod that impacts on bivalve species, reducing local biodiversity (Uyan & Aral 2003). Rapid distribution and increased biomass of *R. venosa* in the Black Sea caused severe damage to the benthic ecosystem (Sahin et al. 2009). In the 1950s, *R. venosa* depleted oyster and mussel populations living near the southern shores of the Cremea and near the Bulgarian coast (Uyan & Aral 2003).

Economic impacts – MODERATE
There have been positive economic benefits of the *R. venosa* introduction in the Black Sea. In the 1980s, the demand for *Rapana spp*. meat on the international market led to massive commercial catches of the *R. venosa* off Turkey and Bulgaria (Uyan & Aral 2003).

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **low)** by consequence for each value category (i.e. **high**, **moderate**, **negligible**, **negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	Moderate	Very Low	Very Low

Anguillicola crassus

Anguillicola crassus appears to have relatively little impact on its native host, *Anguilla japonica* (Japanese eel) (National Estuarine and Marine Exotic Species Information System [NEMESIS 2005b]). However, its introduction to Europe has had severe effects on the culture of European eels, *A. anguilla* (NEMESIS 2005b). *Anguillicola* infection occurs when eels ingest an infected copepod or a paratenic host fish and the nematodes move from the digestive tract into the swimbladder (NEMESIS 2005b). They develop in the swimbladder wall, then mature nematodes move into the swimbladder lumen (NEMESIS 2005b). *Anguillicola* infection can result in inflammation and connective tissue formation in the swimbladder wall which causes decreased swimbladder function (NEMESIS 2005b). After introduction to Europe, this nematode successfully colonised most European countries throughout the 1980s, especially in freshwater environments (Didziulis 2006). *A. crassus* has also been introduced to the United States where its introduced host is the American eel, *A. rostrata* (NEMESIS 2005b).

Common names:
Eel swimbladder nematode, parasitic nematode.

Distribution:
Found in five of the 18 IUCN bioregions (see Figure 2).

Native: Inland waters of Asia and East Asian Seas (Vietnam).

Introduced: North West Atlantic, North East Atlantic, Baltic and Wider Caribbean Sea.

Larval period:
Planktonic larval stage is about 11 days (NEMESIS 2005b). Larvae survival rates highest in freshwater, but can occur in salinities of up to 30 ppt (NEMESIS 2005b).

Temperature tolerance:
Inferred: -2.9 °C to 32.7 °C.
Physiological: 10 °C to 30 °C for reproduction (NEMESIS 2005b).

Inoculation likelihood: VERY LOW

Biofouling association rank – NEGLIGIBLE
A. crassus is thought to have arrived in Europe with eels imported from south-eastern Asia (Didziulis 2006). The main dispersal vector is thought to be the uncontrolled intercontinental transfer of live eels (Didziulis 2006).

Transport pressure rank – LOW
Australian trade with the IUCN bioregions where *A. crassus* is found represents 28.5% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 35% representing a **low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
A. crassus can have significant negative effects on wild European eels (*A. anguilla*). High rates of infection of wild *A. anguilla* resulted in a slight reduction in length-weight ratios, decreased oxygen content in swimbladder gas and slower swimming speed (citations within NEMESIS 2005b). The nematode is expected to have serious impacts on American eel (*A. rostrata*) populations, but these will be difficult to differentiate from pollution, habitat destruction and other human-caused environmental changes (NEMESIS 2005b).

Economic impacts – HIGH
A. crassus causes mortality, decreased growth and reduced swimming speed on cultured European eels (*A. anguilla*) that have been raised in ponds from wild-caught elvers (NEMESIS 2005b). Infection rates as high as 90% have been observed on *A. rostrata* in some regions of Chesapeake Bay, however, the impact of this nematode on eel populations in this region is unknown (NEMESIS 2005b). The nematode has caused extensive mortality of cultured *A. rostrata* (Ooi et al. in NEMESIS 2005b) and is expected to adversely impact wild populations (NEMESIS 2005b).

Social/cultural impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **very low)** by consequence for each value category (i.e. **moderate, high, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Moderate	Very low	Very low

Cliona thoosina

Cliona thoosina is a boring sponge found on rocks and shells on the sea floor. It commonly bores holes in the objects on which it lives (Prince William Sound Regional Advisory Council 2005). It can reproduce clonally (asexually) and sexually with fragmentation, mainly resulting from current or wave action (Prince William Sound Regional Advisory Council 2005). *C. thoosina* is an oviparous species. Sexual reproduction is achieved by the release of sperm into the water, internal fertilisation occurs in the receiving sponge and zygotes are released into the water where they complete their development (Prince William Sound Regional Advisory Council 2005).

Common name:
Boring sponge.

Distribution:
Found in two of the 18 IUCN bioregions (see Figure 2). The current native distribution is unknown with the taxonomy unresolved (proposed synonymy with species in the Mediterranean, Chile and Japan but its origin and present distribution are unknown [Ruiz et al. 2006]).

Cryptogenic: Mediterranean.

Introduced: North East Pacific (Alaska; Prince William Sound Regional Advisory Council 2005).

Larval period:
C. thoosina larvae are short-lived (one to two days) and are normally released at dawn in response to a light cue (Prince William Sound Regional Advisory Council 2005).

Temperature tolerance:
Inferred: -2.9°C to 32.4 °C.
Physiological: No information available.

Inoculation likelihood: LOW

Biofouling association rank – LOW
C. thoosina was most likely introduced into Alaska in association with aquaculture transfers of oyster spat (Prince William Sound Regional Advisory Council 2005). It may also have been introduced via ballast water (Ray 2005).

Transport pressure rank – VERY LOW
Australian trade with the IUCN bioregions where *C. thoosina* is found represents 9.8% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 11.8% representing a **very low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – HIGH
C. thoosina encrusts the surface of mollusc shells–particularly oysters and clams–and secretes enzymes that etch the shell (Ray 2005; Ruiz et al. 2006). The weakening of the shell makes the mollusc more vulnerable to predators such as crabs and birds (Prince William Sound Regional Advisory Council 2005). In severe cases *C. thoosina* can kill the host mollusc (Prince William Sound Regional Advisory Council 2005).

Economic impacts – HIGH
C. thoosina infestations can be harmful to commercial oysters and clams by eroding and sometimes dissolving the shells, thereby increasing the vulnerability of the shellfish to predators (Ruiz et al. 2006). The infestations can also reduce the appeal of the mollusc to human consumers (Prince William Sound Regional Advisory Council 2005; Ruiz et al. 2006).

Social/cultural impacts – MODERATE
C. thoosina infestations can reduce the appeal of the host shellfish to human consumers (Prince William Sound Regional Advisory Council 2005; Ruiz et al. 2006).

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **high, high, moderate, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
High	High	Moderate	Low

Gelliodes fibrosa

The encrusting sponge *Gelliodes fibrosa* is a shallow water species found in biofouling communities (i.e. pier pilings, floating docks) of the major island harbours of Hawaii (Bishop Museum & University of Hawaii 2005; O'Connor et al. 2008). It is also found on shallow reef patches and may be a threat to coral reef patches in protected habitats (O'Connor et al. 2008). *G. fibrosa* most commonly occurs as a thick encrusting blue-grey mat with anastomosing and meandering branches (Bishop Museum & University of Hawaii 2005). Like most sponges, *G. fibrosa* is probably capable of asexual reproduction by fragmentation, but details regarding sexual reproduction of this species are unknown (Eldredge & Smith 2001).

Common name:
Grey encrusting sponge.

Distribution:
Found in two of the 18 IUCN Bioregions (see Figure 2).

Native: East Asian Seas (Phillipines; Bishop Museum & University of Hawaii 2005).

Introduced: South Pacific (Hawaii and possibly Guam; Bishop Museum & University of Hawaii 2005).

Larval period:
No information available.

Temperature tolerance:
Inferred: 17.6 °C to 32.7 °C.
Physiological: No information available.

Inoculation likelihood: LOW

Biofouling association rank – LOW
G. fibrosa was introduced to Hawaii through biofouling on vessels' hulls (Bishop Museum & University of Hawaii 2005). *G. fibrosa* was found on the hull of a floating dry-dock brought to Pearl Harbor, Hawaii from the Philippines in 1992 (Godwin 2003).

Transport pressure rank – LOW
Australian trade with the IUCN bioregions where *G. fibrosa* is found represents 23.2% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 29.6% representing a **low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – MODERATE
In Hawaii, *G. fibrosa* is found encrusting the shaded underside of plate corals on patch reefs (Bishop Museum & University of Hawaii 2005). It may be a possible threat to corals in protected habitats, competing for space with native invertebrates (Bishop Museum & University of Hawaii 2005).

Economic impacts – NEGLIGIBLE
No information available.

Social impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **moderate, negligible, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Moderate	Low	Low	Low

Bonamia ostreae

Bonamia ostreae is an intrahaemocytic protistan parasite of the European flat oyster, *Ostrea edulis*. It parasitises the blood cells (haemocytes) and the cells of oyster gills (Culloty & Mulcahy 2007) causing bonamiosis (Arzul et al. 2009). *Bonamiosis* is a disease of oysters caused by parasites of the genus Bonamia (Culloty & Mulcahy 2007). *B. ostreae* has been described in various ecosystems from estuaries to open sea (Arzul et al. 2009). The complete life cycle of *B. ostreae* is uncertain (Culloty & Mulcahy 2007). Based on the presence of haplosporosomes and molecular analysis, *B. ostreae* is in the taxonomic group Haplosporidia, although a spore stage has never been observed (Culloty & Mulcahy 2007).

Common names:
Bonamia, Haplosporidian parasite.

Distribution:
Found in three of the 18 IUCN bioregions (see Figure 2).

Native: Mediterranean.

Introduced: North West Atlantic and North East Atlantic.

Larval period:
No information available.

Temperature tolerance:
Inferred: -2.9 °C to 32.4 °C.
Physiological: Arzul et al. (2009) investigated the effect of temperature (4 °C, 15 °C and 25 °C) on the survival of parasites maintained in vitro in seawater and showed that *B. ostreae* had lower survival at 25 °C compared to 4 °C and 15 °C.

Inoculation likelihood: LOW

Biofouling association rank – LOW
B. ostreae is believed to be spread by movements of infected oysters (Culloty & Mulcahy 2007). It is not a biofouling organism although its host *(O. edulis*) may be spread through biofouling.

Transport pressure rank – VERY LOW
Australian trade with the IUCN bioregions where *B. ostreae* is found represents 11.4% of the nation's total trade. Once the additional weighting is applied to the different vessel types to account for the mean duration in port in various bioregions, the average increases to the equivalent of 12.8% representing a **very low** likelihood of transport.

Consequence:

Consequence was evaluated based on literature assessments.

Environmental impacts – NEGLIGIBLE
No information available.

Economic impacts – HIGH
B. ostreae is responsible for a serious decline in the aquaculture production of the European flat oyster, *O. edulis* (Naciri-Graven et al. 1998; Launey et al. 2001; Lallias et al. 2008). Prophylactic measures were taken to sustain oyster farming, but the continuing presence of *B. ostreae* and another parasite (Marteilia refringens) led to the initiation of a program to select for resistant oysters (Naciri-Graven et al. 1998). The program was based on mass selection of oysters and parasite inoculation or natural infections (Naciri-Graven et al. 1998). Naciri-Graven et al. (1998) reported no measurable natural resistance of *O. edulis* to *B. ostreae* in the wild.

Social impacts – NEGLIGIBLE
No information available.

Human health impacts – NEGLIGIBLE
No information available.

Risks:

Multiplying the inoculation likelihood (i.e. **low**) by consequence for each value category (i.e. **negligible, high, negligible, negligible**) results in the following risk categorisations across all vessel types and in at least one voyage duration.

ENVIRONMENTAL	ECONOMIC	SOCIAL/CULTURAL	HUMAN HEALTH
Low	High	Low	Low

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