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

An Australian Government Initiative

SHORT REPORT: VESSEL BIOFOULING RISK ASSESSMENT

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Short Report: Vessel Biofouling Risk Assessment

Commissioned by

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This is a summary version of a full risk assessment, *Vessel biofouling risk assessment,* commissioned by DAFF. The full report is available electronically by contacting the Invasive Marine Species Program at IMS-Program@daff.gov.au

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1.0 Introduction

The human-mediated introduction of non-indigenous marine species into new locations can have catastrophic ecological, economic and social consequences (Carlton 1996, 2001; Pimentel et al. 2000; Hewitt 2003). For example, associated damages and costs of controlling aquatic invaders in the United States are estimated to be US$9 billion annually (Pimentel et al. 2000).

The movement of vessels has been identified as the single most important vector for the dispersal of non-indigenous marine species around the world. For the past three decades, ballast water discharges from commercial vessels were thought to be the most significant mechanism for the dispersal of non-indigenous marine species, however recent research suggests that more non-indigenous marine species introductions are attributable to vessel biofouling than any other mechanism (Hewitt et al. 1999, 2004; Mineur et al. 2007).

A risk assessment to identify and determine the quarantine risk to Australia associated with the entry, establishment and spread of marine pest species as biofouling has been conducted. The *Species biofouling risk assessment* (SBRA) (Hewitt et al. 2011), assessed over 1781 marine and estuarine species that have been introduced into areas outside their natural range. The SBRA identified 56 species of concern (SOC) that are not currently known to be present in Australia, have a high probability of arriving in Australian waters as biofouling on international vessels and have the potential to cause unacceptable impacts to environmental, economic, social/cultural or human health values.

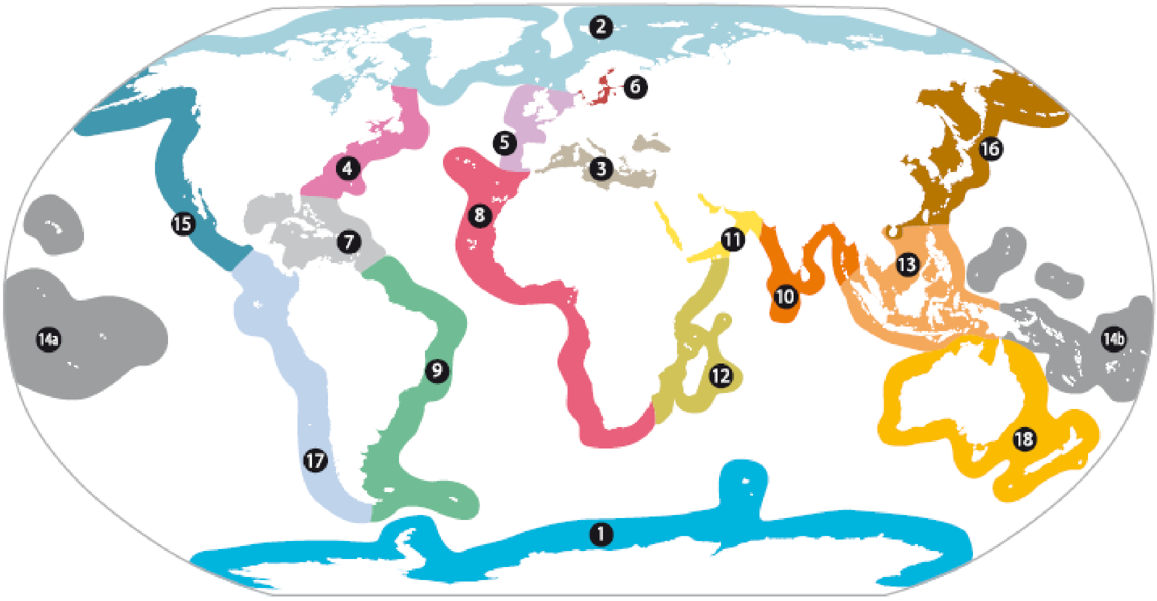
The objective of this *Vessel biofouling risk assessment* (VBRA) was to analyse the voyage history of vessels arriving in Australia to determine the relative biofouling risks of individual vessels, vessel types, subcategories and categories based on their entries into bioregions where the 56 SOC were known to be present.

1.1 Global distribution of species of concern

For the purposes of the SBRA and VBRA, the marine ecosystems of the world were divided into regions using a modified version of the 18 large-scale World Conservation Union (IUCN) marine bioregions (Kelleher et al. 1995) identified in Hewitt and Campbell (2010) (Figure 1). Global distributions of SOC were derived from the literature as described by Hewitt and Campbell (2010) and further expanded on in Hewitt et al. (2011) (Figure 2).

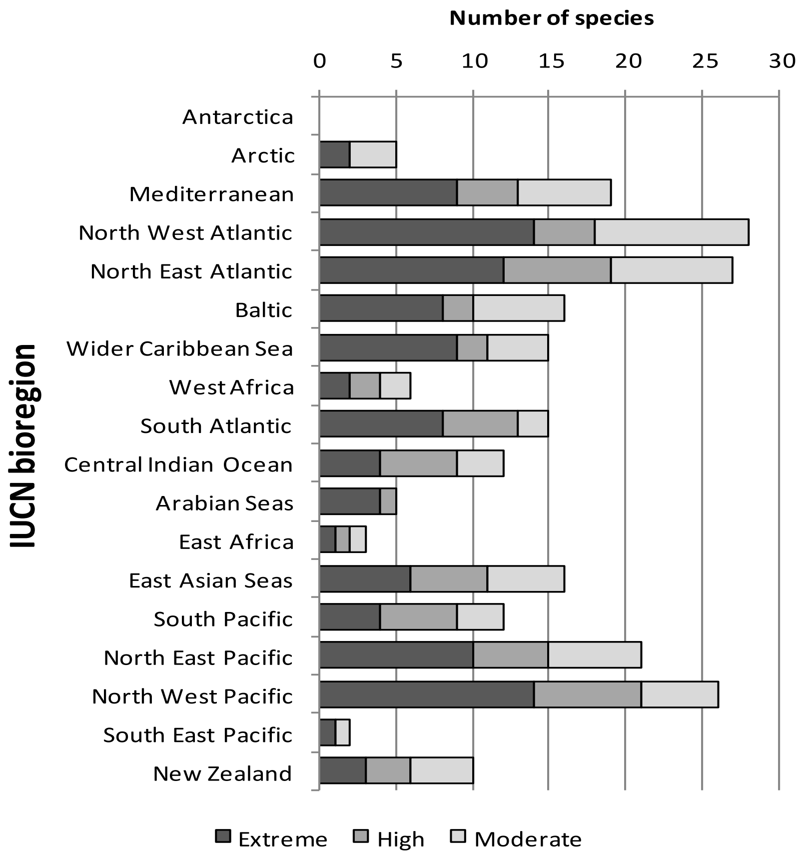
Unfortunately, many regions of the world have not had significant biological evaluations undertaken of their marine environments, resulting in poor recognition of marine invasions. These regions include the high (Antarctic and Arctic) and low (e.g. East Asian Seas, South Pacific, Central Indian Ocean) latitude systems. The Hewitt and Campbell (2010) evaluation, and subsequent risk assessments (Hewitt et al. 2011; and the VBRA herein) are based upon the current state of knowledge of marine invasions.

Figure 1: The 18 IUCN bioregions as defined by Kelleher et al. (1995) and modified from 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.

Figure 2: Known global distribution of SOC, differentiating moderate, high and extreme risk species. Further information on the SOC can be found in the *Species biofouling risk assessment* (Hewitt et al. 2011).



2.0 Methods

2.1 Assessment rationale

The SBRA determined the overall inoculation likelihood for SOC across all vessels, vessel types, subcategories and categories, thus providing the basis for more focused risk management. The intention of this VBRA is to determine how the likelihood component of this risk is attributed across individual vessels, vessel types and vessel sub-categories and categories, and calculating the probability of at least one SOC being present on the vessel upon arrival to Australia.

The SBRA and this assessment evaluated vessels entering Australia between 1 January 2002 and 31 December 2007. The following datasets were used:

- the Australian Quarantine and Inspection Service (AQIS) Pratique dataset representing AQIS records collected upon a vessel's first entry to Australia from 2003 to 2007, specifically for recreational vessel (<25m) entries

- the Australian Fisheries Management Authority (AFMA) dataset for Illegal Foreign Fishing Vessels (IFFV) apprehensions from 2002 to 2007
- the Lloyds Maritime Intelligence Unit (Lloyds MIU) dataset, representing the last 10 ports of call and next 10 ports of call for commercial, petroleum, naval, non-trading and commercial fishing entering an Australian port between 1 January 2002 and 31 December 2007.

The VBRA was based on analysis of voyage histories of vessels that arrived in Australia between 1 January 2002 and 31 December 2007. The analysis included commercial vessels, petroleum vessels, non-trading vessels (including recreational vessels >25m), naval vessels, commercial fishing vessels, recreational vessels (<25 m) and illegal foreign fishing vessels (IFFVs). The relative likelihood of vessels carrying each of the SOC to Australia as biofouling was evaluated based on time spent in infected ports.

2.2 Vessel categories, subcategories and types

Vessels were categorised to allow for a finer scale assessment of transport probabilities. Vessel categories were identical to those in the SBRA (Hewitt et al. 2011), but also included the following subcategories:

- commercial vessels, including merchant vessels and cruise ships
- petroleum production and exploration industry vessels, including offshore anchor handling; support and supply vessels; pipe laying vessels; drilling platforms/ships and floating production, storage and offloading vessels
- 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 recreational vessels >25m in length
- commercial 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
- IFFVs differentiated from commercial fishing vessels due to behaviour and different regulatory controls
- recreational vessels, which incorporates yachts <25m in length, differentiated due to regulatory controls in Australia.

2.3 Vessel movement overview

From 2002-2007, Australia had approximately 15 000 international vessel entries per annum (including recreational vessels and apprehended IFFVs) and the fleet entering Australia had traded with all global bioregions at some point during the period. More than 89% of vessel arrivals in Australia were in the commercial category. The most frequent vessel origins between 2002 and 2007 were the North West Pacific followed by East Asian Seas and the South Pacific. Transport patterns differed between provinces of Australia and changed through time, with increases over time in trade from the North West Pacific (≈35%) and East Asian Seas (≈20%) and moderate decreases (<5%) in other regions.

The transport patterns of small (<25m) recreational vessels and apprehended IFFVs are more restricted due to the poor information coverage. Voyage history, apart from their Last Port of Call (LPOC), was not available for these vessels. Recreational vessels largely arrived from the South Pacific or East Asian Seas, however this represents their LPOC rather than their home port. IFFVs largely arrived from the East Asian Seas and South Pacific.

2.4 Risk assessment assumptions

It was beyond the scope of the current project to include all factors that may influence the likelihood of SOC successfully arriving in Australia. For example vessel age, size, hull complexity, voyage speed, time since dry-docking or in-water cleaning and the seasonality of port visits or port stays are believed to contribute to biofouling transfers on vessels (e.g. Coutts 1999; Minchin & Gollasch 2003; Mineur et al. 2007; Davidson et al. 2009a, b). Additionally, the influence of repeated inoculations of a species to a single location (such as a port), commonly referred to as 'propagule pressure' (*sensu* Ricciardi and MacIsaac 2000), will influence the ability of a species to successfully establish in a new location (see Johnstone et al. 2009). The relative importance of these factors in the invasion process for biofouling-mediated species introductions remains poorly understood (e.g. Fofonoff et al. 2003; Davidson et al. 2009a, b; Hewitt et al. 2009a, b). As a consequence, the transport risk in this report has been evaluated based on the following assumptions:

1. *Species detected in a bioregion were assumed to be present in all areas (ports) of that bioregion*. This is a necessarily conservative assumption. However, due to the poor implementation of biological surveys in many regions (see Campbell et al. 2007), the long delays between evaluations or detections and reporting in the literature, and the ability of invading species to disperse naturally by coastal currents as well as domestic vessel activities (e.g. Grosholz & Ruiz 1995; de Raveira et al. 2007; Davidson et al. 2009a, b; Hewitt et al. 2009a, b), this assumption is pragmatic.

2. *Each vessel visit to a bioregion is an independent opportunity for vessel infection.* The number of visits to a bioregion will increase the opportunities for a SOC present in the bioregion to settle on the vessel.

3. *The opportunity for a SOC to settle on a vessel increases with more time spent in infected ports.* The longer vessels spend in infected ports, the greater the risk posed by each vessel. Literature evaluations of biofouling accumulation support this assumption (e.g. Carlton & Hodder 1995; Floerl 2002; Lewis et al. 2004; Floerl & Inglis 2005), however do not indicate the shape of the relationship.

4. *The likelihood of a SOC being transported to Australia is assumed to increase with increased time since previous out-of-water cleaning.* The time since previous out-of-water cleaning (typically equivalent to the in-service period between dry-dockings and/or the age of antifouling coating) has also been shown to be a very important factor influencing biofouling abundance and diversity (e.g. Coutts 1999). The period of in-water service since last out-of-water cleaning represents the total time available for the accumulation of species and correlates with the increase in biofouling biomass and diversity of biofouling organisms.

2.5 Vessel numbers and voyage durations

Individual vessel entries were assessed for the probability of at least one SOC being present across three voyage durations: LPOC, one-year and five-year. Only vessels that made entries into both Australian and non-Australian ports *during the specific voyage duration being assessed* (see below) were included in the assessment. The Lloyds MIU dataset did not include the complete voyage histories of all vessels during the 2002 to 2007 period. Consequently, only those vessels for which complete voyage histories over one-year and five-year durations were assessed. The total number of vessels was different for each of the voyage durations assessed.

LPOC: based on each vessel's records of entry into non-Australian ports immediately prior to the entry into an Australian port during the period from 1 January 2002 to 31 December 2007.

One-year: based on each vessel's records of port entries for the 12 months immediately prior to entry into an Australian port during the period from 1 January 2002 to 31 December 2007. Only vessels for which 12 months of voyage history exists prior to entry into Australia were included in this assessment. In many instances, individual vessels made multiple Australian entries during the 12-month period; each Australian entry was evaluated independently.

Five-year: based on each vessel's records of entries into non-Australian ports for the five years immediately prior to the entry into an Australian port during the period from 1 January 2002 to 31 December 2007. Only vessels for which five years of voyage history exists prior to entry into Australia were included in this assessment.

2.6 Probability

Each vessel's voyage history was evaluated across the three voyage durations—LPOC, one-year and five-year—to calculate the probability of a vessel transporting each SOC. This calculation comprised two components: the probability of a vessel's exposure to SOC, multiplied by the probability that if exposed the vessel becomes infected. These probabilities were calculated for each SOC independently.

These probabilities were then used to compare individual vessels, vessel types, subcategories and categories to determine those elements that exhibited highest probabilities of carrying at least one SOC ($P_{\text{at least one SOC}}$) and for identifying vessel behaviours associated with higher risks. Risk was also determined by using $P_{\text{at least one SOC}}$ as a likelihood score, multiplied by consequence, calculated here as the proportion of SOC in the categories, a) all SOC; b) high and extreme SOC; and c) extreme SOC.

3.0 Summary of results and discussion

The results presented here clearly demonstrate that vessel biofouling remains a persistent threat to Australia. More than 99% of vessel entries were identified as having a non-zero probability of transporting at least one species of concern (SOC), regardless of the voyage duration assessed (LPOC, 1 year or 5 year). This aligns with the current recognition that levels of biofouling on commercial vessels remains high despite active antifouling prevention (e.g., Coutts 1999; Coutts and Taylor 2004; Mineur et al. 2007, Davidson et al. 2009a, b; Wanless et al. 2010, Yeo et al. 2010).

The results suggest that vessels can vary significantly in their propensity to transfer species, both in terms of likelihoods (probability of at least one SOC being present) as well as consequence (the total proportion of SOC likely to be present on any one vessel). While probabilities of transferring at least one SOC were low for individual vessels, the variation across vessels was sufficient to identify groups of vessels posing greater risk. The majority of this risk is associated with a restricted suite of vessels, vessel types and vessel subcategories and categories providing an opportunity to focus management efforts although the range of variability is high for most groups.

The consideration of varying voyage durations of assessment provided insight to the information needs for future management. LPOC evaluations are restricted in the information available to determine vessel infection (see discussion of limitations below), consequently the pattern of risk is largely a function of the LPOC bioregion – vessels trading with bioregions that are infected with the greatest number of SOC will consequently pose the greatest risk regardless of vessel type or category. In contrast, one year voyage durations provide the opportunity to determine the influence of individual vessel behaviours on risk. This study identified that the highest relative risk vessels were those that also had the greatest number of foreign port entries, with no correlation to duration in foreign ports or number of bioregions visited. The vessels in this category were all commercial vessels, primarily container vessels and roll-on roll-off vessels. Five year voyage evaluations provided the greatest differentiation of high and low risk vessels. Overall values for $P_{\text{at least one SOC}}$ increased in contrast to one year and LPOC evaluations. The highest risk vessels were all commercial vessels (1 bulk carrier, 2 roll-on roll-off vessels, 9 fully cellular container vessels and 7 vehicle carriers).

The highest relative risk vessel types were bulk carriers and fully cellular container vessels (both commercial vessel types) and recreational vessels (<25m) based on LPOC data. The high $P_{\text{at least one SOC}}$ scores for these vessel types were correlated with a high number of vessel entries into foreign ports suggesting that the opportunity for infection was driving these higher risks. A group of non-trading vessels (crane barge, grab dredger, hopper barge, and patrol ship) and one fishing vessel (fish carrier) were the lowest risk vessel types in the assessment. All of these low risk vessel types were represented by a single vessel in the dataset.

For LPOC voyage durations, the highest relative risk vessel subcategories were IFFVs and commercial bulk carrier vessels, followed by petroleum drilling vessel subcategory. In contrast, one and five year voyage duration evaluations identified a reduction in variability for all subcategories other than commercial vessels, with highest risks posed by commercial cruise, roll-on roll-off, tanker and container vessel, and non-trading miscellaneous subcategories. Non-trading miscellaneous includes semisubmersible heavy lift vessels, cable ships, crane ships and training vessels.

The highest relative risk vessel categories were commercial vessels and recreational vessels (<25m) assessed with the LPOC dataset. These vessel categories had higher average $P_{\text{at least one SOC}}$ scores and higher maximum values than other vessel categories across all SOC evaluations. Again, high $P_{\text{at least one SOC}}$ scores were correlated with larger numbers of foreign port entries within vessel categories. Naval vessels and "unallocated" vessel categories represented the lowest relative risks; however it should be noted that these two categories were represented by 4 vessels in total.

The relative risks associated with several vessel types, subcategories and categories were not as anticipated. In part this was due to data limitations and risk model constraints (discussed below). As discussed previously, IFFV and recreational vessels (<25m) were restricted to LPOC evaluations alone and the lack of information on port stay durations largely precluded any ability to evaluate vessel behaviour correlates. Similarly, naval vessels were poorly represented in the dataset despite Australia having numerous entries of both domestic and foreign vessels. Naval vessels claiming sovereign immunity are not reported to Lloyds MIU creating significant limits to the evaluation of naval vessels as a group in this study.

As a group, several slow-moving vessel groups (types and subcategories) in non-trading and petroleum vessel categories were rarely identified in the highest relative risk categories throughout this assessment. In evaluating the dataset, it is apparent that several slow moving vessel types are under-represented including barges, dredges and oil rigs. Several authors have detected high biofouling biomass on slow moving vessels with high residence time (port stays) (Foster and Willan 1979, Hay and Dodgshun 1997, Coutts 2002, Wanless et al. 2010), suggesting that these vessels groups that these may represent higher risks than represented in the evaluation here.

As discussed by numerous authors, (e.g., Schneider et al. 1998; Ruiz et al. 2000; Johnson et al 2001; Ruiz and Carlton 2003; Davidson et al. 2009a, b) information on transport patterns and probabilities are a fundamental first step in developing predictive models of invasion risk. Here we assessed risk largely on the basis of voyage history using a comprehensive dataset for Australian vessel entries for the period 2002-2007. This study evaluated the likelihood of transport from infected waters by evaluating vessel infection probability as a function of entry into and time spent in bioregions infected by each of the SOC during voyages of differing lengths (LPOC, 1 year, 5 year).

It is important to recognise the limitations of this VBRA and these are discussed further below.

3.1 Limitations of this study

The dataset used herein had severe limitations – not all vessel categories had equivalent coverage, with IFFVs and recreational vessels (<25m) having information restricted to LPOC only. LPOC data provides a limited amount of information to evaluate the probability of individual vessels transporting SOC. Given the accumulation of biofouling begins as soon as a vessel enters the water, the need to evaluate a vessel's voyage history since the last dry-docking, antifouling paint application, or in-water cleaning is a fundamental requirement to ascertain the invasion risk posed by a vessel. Previous studies have used "guestimates" to derive probabilities of transport, generally assuming that ~1% (0.01) of vessels are likely to carry a single species (Schneider et al. 1998). More recent studies suggest that this estimate is low for many known invaders (e.g., Johnson et al 2001), however the values are likely to be specific to voyage patterns including seasonally-specific patterns of infection probability.

Given the constraints of vessel movement data, estimation of the likelihood of transport could only be based on voyage history. Accordingly, several factors, such as time since out of water clean, voyage speed, voyage duration, vessel age, size, hull complexity, and seasonality which are known to influence biofouling development (e.g., Coutts 1999; Minchin and Gollasch 2003; Floerl et al. 2005; Mineur et al. 2007, Davidson et al. 2009a, b), were not included in the risk analysis. Some of these factors are known to be important drivers of abundance and presumably diversity of biofouling on vessel hulls.

3.2 Discrepancies between risk assessment outcomes and apparent invasion success for SOC

Despite the 13 760 vessels which collectively made a total of 60 093 entries into Australia over the six years during which the data for this report was gathered, none of the SOC are known to have successfully established in Australia. The SOC were explicitly selected because they had yet to establish in Australia (Hewitt et al. 2011), and there is a moderate likelihood that at least some of the vessels in the datasets would have been carrying some of the SOC. While the lack of successful establishments confirms that the absolute risk posed by any single vessel is very low as indicated in our assessments, (even if a SOC has settled on the vessel), the issues surrounding why the arrival or establishment of one of the SOC may not have been recognised is explored further below.

This assessment assumed that, once a SOC settled on a vessel, the likelihood that the voyage transit would eliminate the species from the vessel was low. It is important to note however, that transit survival can be influenced by a number of voyage elements: the changing water conditions between port-ocean-port environments, vessel speed, oceanic conditions, etc.

Even if SOC had been successfully transported to Australia, there are a number of reasons why the arrival of one of the SOC would not have been recognised. The arrival of infected vessels in Australia does not necessarily result in the transfer of a species from the vessel to the local environment. The SOC may not have reproduced or been dislodged from the vessel. Even if the port had been inoculated, a population could have failed to establish. We currently estimate this failure rate as being very high due to direct predation and competition with resident species (e.g., deRivera et al. 2005), Allee effects[3] resulting in gamete dilution and reducing fertilisation success, and founder effects impacting on small populations (e.g., Stephens et al. 1999; Drake and Lodge 2006). The release of relatively small numbers of gametes or fragments of individuals is unlikely to result in sufficient population sizes to surmount these obstacles.

One element of the propagule pressure debate is the need for multiple inoculations *in the same location* to establish the genetic diversity sufficient to surmount these barriers. As discussed previously, neither this VBRA nor the SBRA evaluated risk at the level of individual Australian ports, but instead conducted the assessment *for the whole of Australia*. As a consequence, a critical element of propagule pressure could not be considered here. When vessel entries are taken for Australia as a whole, entries in the commercial vessel category, bulk carrier vessel and fully cellular container vessel types represent the highest number of vessel entries, and therefore the highest relative risks based on propagule pressure for all of Australia.

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[3] Allee effect (named after the author Warder Allee) refers to the effect of population size on reproduction and survival of individuals (Allee 1931). Specifically, the reproduction and survival rates of individuals increase with population density (Stephens et al. 1999).

Lastly, a SOC may have successfully infected a vessel, been transported across the oceans and inoculated an Australian port, however due to a range of factors, a detection or the presence of a SOC in the receiving environment may have been overlooked. Under Australia's National System for the Prevention and Management of Marine Pest Incursions (The National System) biennial surveys of marine pests in the 'busiest' ports are intended. However, during 2002-2007 for which the data was gathered, surveillance activity of major ports for any non-indigenous species (including SOC) has been minimal (two ports surveyed in this period, Hobart 2002 and Adelaide 2007). Furthermore, one of Australia's busiest ports, Dampier has yet to be surveyed. Thus, it remains possible that some of the SOC are present in Australia but remain undetected.

The use of highly toxic but effective TBT-based antifouling coatings may have also contributed to the apparent lack of establishment of SOC in Australia. While such coatings may have prevented SOC from establishing in Australia during the period covered by the database, from September 2008 an international convention banning the use of TBT came into force. The transition to copper and non-biocidal coatings is likely to impact organism settlement and retention on vessel hulls, potentially causing a major shift in shipping related species transfers (Nehring 2001; Fofonoff et al. 2003; Davidson et al. 2009a, b).

Another aspect of the phasing out of TBT usage in relation to invasion success relates to toxicity of port regions (e.g., Dafforn et al. 2008). Most port regions are found in sheltered areas with relatively high TBT loads, which is seen as an important feature in suppressing development and recruitment of sensitive life-stages (Minchin and Gollasch 2003). However, once TBT-related toxin levels decline, it is expected that a wider range of organisms will find port regions suitable for colonisation and invasion rates may increase.

3.3 Management implications

The aim of this study was to identify vessels, types and risk profiles that pose the highest probability of translocating SOC to Australia, with findings able to assist with policy development and provide information on a possible targeted vessel inspection regime. While probabilities of transferring at least one SOC were low for individual vessels, the highest risk vessel types were bulk carriers and fully cellularised container vessels (both in the commercial vessel category) and recreational vessels (<25m) based on LPOC data. There were 3941 bulk carriers, 546 fully cellular container vessels and 5715 recreational vessels that visited Australia between 2002 and 2007 –a total of 10 202 vessels. While it might be feasible for quarantine officers to use 'cameras on a stick' technology (e.g. Snake Eye III, Titan Video Stick, SCUBAR, etc) to inspect recreational vessels, commercial divers would need to be engaged to inspect commercial vessels.

The saying that, "An ounce of prevention is worth a pound of cure" has often been cited as the most appropriate adage for a biosecurity motto. This is clearly the case for the marine environment, where early interventions can reduce the need for control and eradication programs with their accompanying costs and uncertain outcomes (e.g. Ruiz & Carlton 2003; Hewitt et al. 2004, 2009a, b; Hewitt & Campbell 2007; Williams & Grosholz 2008). A large effort is expended internationally on education and awareness-raising. For marine biofouling, a significant first step is self-management of stakeholders, specifically vessel owners and operators. Regular maintenance, including out-of-water cleaning and paint application (e.g. dry-docking) will reduce the accumulation of biofouling species on vessels.

The Australian Government has developed voluntary national biofouling management guidelines for commercial, non-trading, recreational and petroleum vessel sectors. These guidelines assist vessel owners to self-manage their risks by reducing the likelihood of accumulating and transferring biofouling to Australia. Successful implementation of these guidelines would act to significantly reduce the likelihood of SOC entry.

Unfortunately, it is highly unlikely that voluntary guidelines will achieve a 100% effective barrier—the border will remain 'leaky' due to accidental or intentional failures to ensure appropriate vessel hull husbandry. It is important to acknowledge that more than 99% of vessel entries were identified as having a non-zero probability of transporting at least one species of concern (SOC), regardless of the voyage duration assessed (LPOC, one-year or five-year). Hence, any one of the ≈12,500 vessel entries to Australia per annum has the potential to introduce SOC.

Therefore, a cost-effective approach is needed to focus efforts on those vessels that have the highest likelihood of being infected with SOC.

3.4 Conclusion

In conclusion, the study importantly identifies that all vessels pose some probability, albeit low, of transferring a SOC to Australian waters. However unavoidable data gaps (discussed above) and conservative modelling assumptions reduce the ability to definitively compare vessels (individual, type, subcategory and category) with respect to their probablity of inoculating a SOC.

Australia remains at risk of biofouling associated introductions, with the majority of risk accumulating in commercial and non-trading vessels based on this model. Recreational and IFFV vessels appear to pose a significant risk, but data limitations preclude more detailed analyses. This risk assessment forms a first attempt, in Australia, to begin to characterise relative vessel risks in relation to their propensity to translocate a SOC to Australian waters. In some senses, attempts to make relative comparisons became a case of attempting to compare 'apples to oranges'. As a result, the approach presented here would greatly benefit from validation and further ground truthing to improve its predictive risk abilities.

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