Australian Government

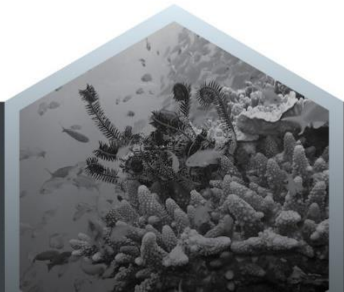
MARINE PESTS

Australian Priority Marine Pest List

Process and outcomes

Prepared by the Australian Bureau of Agricultural and Resource Economics and Sciences

Nationally agreed guidance material endorsed by the Marine Pest Sectoral Committee



Cataloguing data

This publication (and any material sourced from it) should be attributed as: MPSC 2018, *Australian Priority Marine Pest List: process and outcomes*, prepared by ABARES, Canberra, May. CC BY 4.0.

This publication is available at marinepests.gov.au/what-we-do/publications

Marine Pest Sectoral Committee Secretariat
Department of Agriculture and Water Resources
GPO 858 Canberra ACT 2601
Telephone 1800 372 746 (local calls) +61 2 6272 5232 (international
Email mpsc@agriculture.gov.au
Web marinepests.gov.au

Acknowledgements

This report to client was commissioned by the Marine Pest Sectoral Committee (MPSC) and funded by the Department of Agriculture and Water Resources as part of the 2015 Review of National Marine Pest Biosecurity. The Australian Priority Marine Pest List task group, with assistance from technical experts, developed the assessment methodology, undertook species assessments, debated species outcomes and have agreed on the preliminary Australian Priority Marine Pest List for consideration by the MPSC. ABARES staff Jessica Evans and Sandra Parsons compiled and reviewed the assessments and prepared this report. The composition of the task group, since its inception in 2014 are as follows (their affiliations are shown in Appendix C): Heidi Alleway, Victoria Aitken, John Barker, Murray Barton, Michelle Besley, Alex Chalupa, Ashley Coutts, Marty Deveney, Sridevi Embar-Gopinath, Tim Glasby, Sonia Gorgula, Sarah Graham, Kylie Higgins, John Lewis, Pat Lewis, Alicia McArdle, Justin McDonald, Dean Paini, Robert Parker, Sandra Parsons, Anita Ramage, Ben Rampano, Tim Riding, Michael Sierp (Inagural Chair), John Virtue (Chair), Melissa Walker and Richard Willan. The task group acknowledges the advice kindly provided by the following technical experts: Shane Ahyong (crustaceans), Charles Griffiths (barnacles), Ingo Ernst, Dianna Jones (barnacles), Chris Glasby (polychaetes), Dean Paini (several groups), Jeff Ross (decapod crustaceans), Lexie Walker (polychaetes), Robin Wilson (polychaetes) and Jeff Wright (decapod crustaceans).

Summary

The Marine Pest Sectoral Committee (MPSC) sought to establish an updated list of priority marine pests in line with the Australian government national policies—the 'National Environmental Biosecurity Response Agreement' (NEBRA) and the 'Established Pests and Diseases of National Significance' (EPDNS). The intention of developing the new APMPL is to facilitate national improvements in marine pest communication, surveillance, preparedness, response and management for pests deemed national priorities. However, it is important to note that the APMPL is not exhaustive, and is primarily a list of examples to aid in these activities.

The MPSC established the Australian Priority Marine Pest List task group (the task group) to populate the APMPL. This report outlines the methodology and process developed by the task group to establish the APMPL and provides information on all species assessed by the task group for consideration on the APMPL. The task group recommends nine species to the MPSC for consideration on the APMPL.

The APMPL scope is to identify species that meet the criteria of the NEBRA for the purpose of responses. It only includes species that meet the criteria of national significance, reasonable likelihood for field identification, and possibility of eradication.

The nine species recommended for the APMPL includes three established and six exotic species. The exotic species chosen are those that are likely to meet the NEBRA criteria; the established species are those for which national management is required to minimise their spread. Inclusion on the APMPL indicates a species is considered as a significant marine pest, and further work is required. This may include the development of national preparedness plans for the exotic species, and revision of national management plans for the established species. These species should be a focus in national improvements in marine pest communication, surveillance, preparedness (including incursion response) and ongoing management.

The proposed established marine pests of national significance are:

- *Undaria pinnatifida* (Japanese kelp)
- *Carcinus maenas* (European shore crab)
- *Asterias amurensis* (northern Pacific seastar).

The proposed exotic marine pests of national significance are:

- *Eriocheir sinensis* (Chinese mitten crab)
- *Rhithropanopeus harrisii* (Harris' mud crab)
- *Perna viridis* (Asian green mussel)
- *Perna perna* (brown mussel)
- *Perna canaliculus* (New Zealand green-lipped mussel)
- *Mytilopsis sallei* (black-striped false mussel).

Contents

Figures

Tables

Introduction

Marine pests are non-native marine plants or animals that are considered to have the potential to harm Australia's marine environment, social amenity, human health and industries. Marine pests may threaten biodiversity through a number of mechanisms such as predation, competition for habitat and altering ecosystems. They can also impact the economy and social amenity, decreasing the activities based in the marine environment such as shipping (for example, through increased fuel costs due to hull fouling), fisheries, aquaculture, tourism and marine infrastructure (Hayes & Sliwa 2003; Hayes et al. 2005; Murphy & Paini 2010; Schultz et al. 2011; Fitridge et al. 2012; Katsanevakis et al. 2014; Berdalet et al. 2015).

Marine pests are primarily transported around the world by anthropogenic vectors. Shipping—followed by aquaculture—represents the major means of introduction of marine invasive species; other common human-assisted pathways include canal construction, and the live seafood and aquarium trades (Molnar et al. 2008). Once introduced into a new location, marine pests may subsequently spread to new locations by these vectors as well as by 'hitchhiking' (for example on fishing gear) and via natural dispersal (Dodgshun, Taylor & Forrest 2007; Relini, Relini & Torchia 2000). In 1999, the introduction and successful eradication of the black-striped false mussel, *Mytilopsis sallei,* in Darwin highlighted to governments the need for an integrated approach to prevent and manage marine pest incursions. This set in force a number of actions to address marine biosecurity in Australia, including the establishment of the National System for the Prevention and Management of Introduced Marine Pest Incursions (the National System). The National System comprised three elements: prevention, emergency response and ongoing management and control of introduced marine pests.

In 2015, the national review of marine pest biosecurity identified the need to revise the approach to the National System to better reflect the current understanding of marine pest impacts and pathways (Department of Agriculture and Water Resources 2015a). The review recommended that a national marine pest biosecurity strategy should be finalised and implemented to set a new direction for the national management of marine pests and replace the National System for the Prevention and Management of Marine Pest Incursions. This includes the development of national monitoring and surveillance strategies to replace the National Monitoring Strategy.

The 2015 national review of marine pest biosecurity also highlighted that prevention should be the focus of marine biosecurity efforts (Department of Agriculture and Water Resources 2015a). In relation to ballast water, Arthur, Summerson & Mazur (2015) concluded from cost comparisons that prevention of incursions of marine pests is generally preferable over the eradication of a marine pest, because prevention focuses on a broader range of species than eradication, and has a higher rate of success. To support the prevention of new incursions, a number of international agreements and guidelines have been developed to prevent the spread of marine pests by shipping and recreational craft. These include the Ballast Water Management Convention for ballast water (IMO 2004) and guidelines for hull fouling (IMO 2011, 2012), which are the primary mechanisms of marine pest spread via vessels (Carlton & Geller 1993). These agreements aim to prevent vessels from transporting marine pests to new locations. However, no risk can ever be reduced to zero. Incursions of new marine pests into Australia and to new jurisdictions (for established species), may still occur.

A number of national policies guide Australian governments and outline to stakeholders how governments may respond to new incursions of introduced species. The National Environmental Biosecurity Response Agreement (NEBRA) sets out emergency response procedures for the event of an incursion of an exotic species to Australia, where the species threatens to impact the environment or social amenity. The Established Pests and Diseases of National Significance (EPDNS) framework sets out the management actions for established species. Both policy documents focus effort to those species that are assessed as having significant impacts and where it is in the national interest to act. This ensures that response efforts direct their attention and limited resources to those species where they have the potential for greatest impact.

A number of 'marine pest lists' currently exist in Australia. These lists include species that have been assessed as of concern due to their potential or documented impacts on the environment, business, social or cultural values and human health. The Consultative Committee on Introduced Marine Pest Emergencies (CCIMPE) Trigger List (CCIMPE trigger list), is an agreed list of marine pests that are considered to have the potential for significant impacts if they were to establish in Australia's marine environment. If a species was detected that was on the CCIMPE trigger list, it would 'trigger' a range of response actions. The CCIMPE trigger list was last reviewed in 2007, and since this time, the new policy framework of the NEBRA and EPDNS have been established to guide marine pest incursion responses and actions. As such, the CCIMPE trigger list is no longer valid to direct the need for emergency responses. However, states and territories continue to report new detections and significant range extensions of CCIMPE trigger list species to CCIMPE.

In keeping with NEBRA and EPDNS, the Marine Pest Sectoral Committee (MPSC) agreed to develop a new list of priority marine pest species, which includes both exotic and established species. For exotic species, those on the APMPL are expected to meet the requirements of a NEBRA response, if the scale and location of the incursion is deemed technically feasible to eradicate. For established species, those on the APMPL are where national collaborative effort is required to limit their further spread (human-mediated) and manage their impacts.

The APMPL will facilitate a nationally coordinated set of actions for those listed species, such as the development of preparedness plans for exotic species and national management plans for established species. The MPSC has agreed that the focus should not be limited to these listed species. The APMPL represents significant marine pests, areas of focus for fostering national improvements in marine pest communication, surveillance, preparedness (including incursion response) and ongoing management.

To populate the APMPL, the MPSC established the APMPL task group (the task group) in 2013. The terms of reference for the task group included the development of an assessment framework, selecting candidate species for assessment, assessment of those species and the recommendation of a list of APMPL species to the MPSC (Appendix A and Appendix B). In 2017, ABARES was commissioned by the MPSC to support the task group by standardising, editing and reviewing species assessments undertaken up to that time and provide a technical report to the MPSC to document the listing process.

Methodology

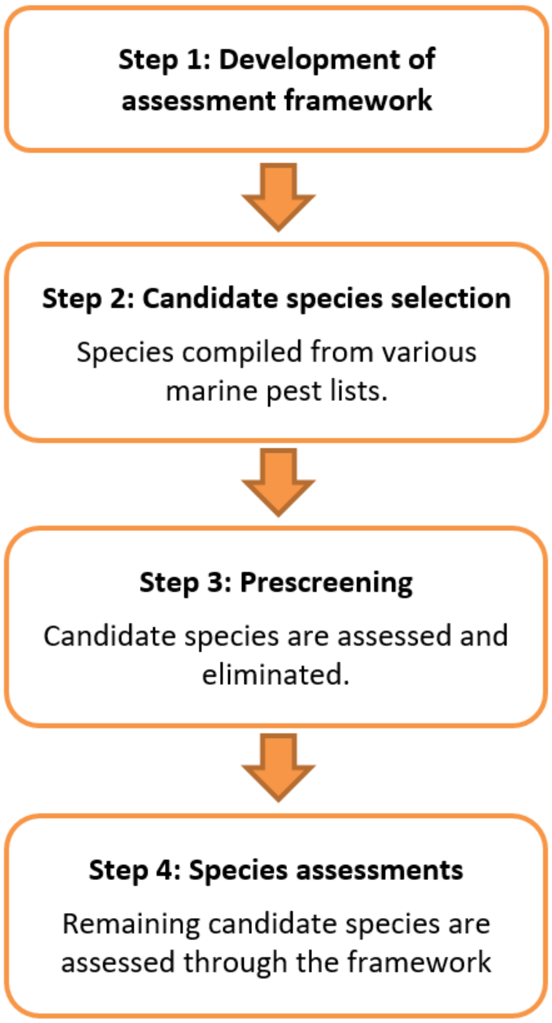
The task group developed the APMPL based on criteria endorsed by the MPSC and the National Biosecurity Committee (NBC) in 2015 (Appendix A). The terms of reference for the task group (Appendix B) include:

- proposing an assessment methodology to MPSC to assess species' marine pest risk, including assessment against the NBC and NEBRA national significance criteria
- undertaking species assessments according to the developed assessment framework
- providing recommendations to the MPSC for species to be considered on the APMPL.

The task group consisted of policy and operational officers from Commonwealth and state and territory governments and Australian marine pest technical experts (Appendix C).

To determine the final list of species to recommend for the APMPL, the task group undertook a series of steps including developing an assessment framework, selecting candidate species, pre-screening species and final assessment. Figure 1provides an overview of these steps.

Figure 1 Steps for recommending species for Australian Priority Marine Pest List



Development of the assessment framework

The first project for the task group was to develop an assessment framework in which to assess species for the APMPL. The objective of the assessment framework was to populate a list of marine pest species of national significance, including:

- exotic pests—species not known to be established in Australia, which would be expected to meet the requirements of a NEBRA response if the scale and/or location of an incursion was technically feasible to eradicate
- established pests—species already introduced to Australia, which would require agreed national collaborative effort to further limit national spread and manage impacts.

The task group agreed on a number of criteria that the assessment framework must meet, including that it be:

- transparent, robust, defensible, flexible and concise
- easy to use—simple language so that it could be understood by policy and technical staff; developed on an accessible platform such as excel or web-based
- applicable to a wide range of taxa
- consistent and provide a clear outcome for differentiating species
- best practice in terms of a decision support system.

The task group discussed a proposed semi-quantitative prioritisation framework at workshops in April and December 2015. However, this was dismissed unanimously in favour of the development of the simpler 'stop/go' approach outlined in the following section. The final agreed framework is comprised of three steps.

Step 1 Stop/go criteria

The 'stop/go' screening criteria are a set of screening rules developed by the task group based on the APMPL listing criteria approved by the MPSC and NBC (Appendix A). Each of the criteria in Step 1 requires a 'true' or 'false' response with species requiring all responses to be 'true' in order to proceed to Step 2. The stop/go criteria and explanatory information for each criterion is in Appendix D, (tables D1 to D3).

Step 2 Impacts

The second step of the assessment framework relates to the impacts of the species. Species that are determined to be invasive—based on the literature or other expert evidence, or where there is some level of uncertainty—then progress to an impact assessment. Potential species must first be determined as likely both to reach high densities and to maintain its invasiveness over time. Species failing these criteria are unlikely to have impacts sufficient to require response and are eliminated from further consideration.

The impact assessment criteria are based on NBC national significance principles (NBC 2016) and the NEBRA. The criteria include an assessment of impacts on the environment, social and cultural values, economy and human health. To meet the NEBRA and NBC 'national significance' requirements, the species must demonstrate that it is likely to have 'significant negative consequences' on at least one of the impact criteria. Significant negative consequences are impacts deemed to be substantially over and above those caused by native species or other naturalised species.

Significant negative consequences for the environment refers to any effects that either would substantially modify habitats or nutrient cycles, or would seriously disrupt the lifecycle (reproduction, feeding and behaviour) of an ecologically significant proportion of the native flora and/or fauna populations in question. Impact criteria for the environment were largely derived from the NEBRA national significance criteria, with examples provided from the EPBC Act 1999 for nationally protected endangered species or communities, ecologically valuable marine species, nationally important places and ecologically valuable places.

Significant negative consequences for social and business impacts relate to those that might seriously disrupt current human usage, practices or profitability. In terms of financial costs, significant negative consequences of a pest, once it became widely established, would be in the order of greater than $10 million per annum in terms of impacts and the pest's management.

Human health impacts were considered to be those where a pest would be likely to cause significant impacts such as illness or physical injury to people resulting in deaths, permanent disabilities and/or substantial long-term health costs to the community.

The assessment criteria for Step 2 are included in Appendix D, Table D4. Once a species has passed Step 1 and Step 2 of the assessment framework, it is deemed suitable for recommendation on the APMPL.

Step 3 Potential distribution and control options

The final step of the process seeks to gain additional information for the consideration of a species, to assist with the development of any emergency response or national plan. This step is not a determinant for the species to be listed on the APMPL. Appendix D outlines the criteria for Step 3, in Table D5.

Candidate species selection

The initial compilation of candidate species for consideration involved the collation of 13 existing Australian and New Zealand marine pest lists (Appendix E). This resulted in an initial candidate list of 158 species.

Pre-screening species for assessment

The 158 species were screened prior to further assessment based on the impact assessments conducted by Murphy and Paini (2010) on marine pests of concern. The marine pests of concern included those on the CCIMPE trigger list, the NIMPIS, the Marine Pest Monitoring List, the Ballast Water Risk Assessment List and the List of Species of Biofouling Concern.

Species impacts were assessed against the four NEBRA criteria: environment, business, public health and people. Each species was assessed against each impact criterion and was scored one of six ranks: negligible (or no information available), very low, low, moderate, high or extreme (Murphy & Paini 2010). Species assessed by Murphy & Paini (2010) as having at least one 'extreme', or one 'high' or at least two 'moderate' impacts were considered for inclusion in the APMPL assessment framework developed by the task group. It was deemed that species assessed as having negligible, very low or low impacts would be unlikely to meet the national significance criteria, and were therefore excluded from further assessment. 76 species were eliminated at this step, leaving 82 species to be further assessed through the assessment framework. Three established species that were originally eliminated were reconsidered by the task group and added back to the candidate list, despite Murphy and Paini (2010) ranking them as having low impacts.

The task group considered the inclusion of a further nine species on advice from experts of emerging marine pest species and the Northern Australia Biosecurity Framework (NABF) Aquatic Biosecurity Capability Project (Northern Australia Marine Pest Hazard Identification Workshop, September 2016).

The 82 species, with additional three species reconsidered by the task group and nine additional species for consideration, meant 94 species progressed to the next stage of the process.

Species assessments

Using the Step 1 Stop/go criteria, a subset of task group members eliminated 40 of the 94 species remaining after pre-screening. This included excluding species that were parasitic; these are covered by the Sub-committee for Aquatic Animal Health (SCAAH). Appendix F provides more details on the species excluded at this step, and the justification used.

Of the remaining 54 species, the task group applied the assessment framework to 51 candidate marine pests. A subset of task group members undertook the assessments—usually two people working together on each species.

Candidate species included:

- 8 algae
- 2 annelids
- 16 arthropods
- 1 bryozoan
- 6 chordates
- 1 echinoderm
- 3 cnidarians
- 14 molluscs.

These assessments formed the basis for discussion amongst the 14 participants at the workshop on 28 and 29 November 2016. Representatives from all jurisdictions participated in the workshop, which included taxonomic, ecological, management and policy expertise. Post-workshop, ABARES reviewed the species assessments, in consultation with the original species assessors. An additional three arthropods were later assessed by members of the task group and technical experts. Detailed species assessments for the 54 species are at Appendix G.

The complete list of 167 species (158 species from original lists and 9 species recommended by the task group and experts) are provided in Appendix E (tables E2 to 18). Also included are the marine pest lists (or expert recommendations) from which the species had been derived (Table E1), and the steps at which species were removed from the assessment process for further consideration (tables E2 to 18).

Assessment outcomes

Based on the assessment framework, the task group recommended nine species (three established and six exotic) for listing on the APMPL by the MPSC. A summary of each species recommended for inclusion on the APMPL is provided in this section.

Established species

Asterias amurensis (northern Pacific seastar)

Asterias amurensis is an invasive starfish, native to China, North Korea, South Korea, Russia and Japan. It was introduced to Tasmania in the 1980s (Buttermore, Turner & Morrice 1994) and has since spread to Victoria. The potential range of this species in Australia determined by sea surface temperature and temperature tolerance modelling suggests that the species could establish in South Australia, New South Wales and Western Australia (Richmond, Darbyshire & Summerson 2010).

A. amurensis is a generalist predator impacting soft sediment communities, particularly bivalve populations (Ross, Johnson & Hewitt 2002; Ross et al. 2004), and has been implicated as a factor in the decline of the endangered spotted handfish (Bruce & Green 1998). The species has had significant impacts on aquaculture and recreational activities due to predation on native and commercially farmed shellfish, particularly scallops and mussels, but could also impact clam and cockle fisheries (Aquenal 2008d).

A. amurensis is most likely spread through ballast water or hull fouling. These pathways need to be effectively managed to prevent translocation and introduction to new jurisdictions.

Given the impacts observed both in Australia and in its native range, and the potential for *A. amurensis* to expand its range and establish in other jurisdictions, the task group agreed that there is a national interest to contain its spread and prevent its establishment in new areas.

Carcinus maenas (European green shore crab)

Carcinus maenas is an invasive species—native to Europe and North Africa—that has been introduced to Australia, South Africa, Japan and North America. The first records of this species in Australia are prior to 1900. In Australia, *C. maenas* is now established in the temperate waters of New South Wales, South Australia, Tasmania and Victoria. It is not known to be established in Western Australia, although a single individual was found in 1965 (Thresher et al. 2003). Western Australia is the only remaining jurisdiction in Australia where it is likely to establish based on potential distribution modelling (Richmond, Darbyshire & Summerson 2010).

C. maenas impacts a range of benthic bivalves (Walton et al. 2002, Ross et al. 2004; Tan & Beal 2015) and may reduce abundances of seagrass (*Zostera*) (Garbary et al. 2014; Neckles 2015). In North America, it has caused declines in commercial shellfish operations (up to 40 per cent in some cases), reduction in native bivalve and shore crab species and indirect impacts on benthic communities (increases) due to a reduction in predators of these communities (Aquenal 2008b and references within). However, there have been few impact studies in Tasmania, which in some cases have indicated significant negative impacts on native bivalve and crab populations in soft sediment habitats (Aquenal 2008b). There have been no comprehensive studies of impacts of *C. maenas* (relative to native species) on aquaculture in Australia, but interviews of NSW oyster farms indicated that up to 30 per cent of stock inside trays or tumblers may be consumed by the crabs (Epe 2012).

Due to the observed negative impacts of *C. maenas* on the environment and industry, containing the species spread via human-mediated transport (ballast, aquaculture) and preventing establishment of this species in Western Australia is a priority.

Undaria pinnatifida (Japanese kelp)

Undaria pinnatifida, native to Japan, Korea and China, is an invasive brown macroalga that has been introduced into and has become established in Australia, Europe, North America and New Zealand. Within Australia, *U. pinnatifida* has become established only in Tasmania and Victoria.

U. pinnatifida is highly invasive, growing rapidly (Australian Emergency Marine Pest Plan 2015), with the potential to outcompete native algal species. It has a range of impacts, including nuisance fouling of vessels, marine structures, shellfish and aquaculture structures (James & Shears 2016).

The potential range of *U. pinnatifida* is determined by sea surface temperature, and temperature tolerance modelling suggests the species could establish in New South Wales, South Australia, Queensland and southern Western Australia (Richmond, Darbyshire & Summerson 2010).

Given the suitability of this species to establish in most jurisdictions across Australia—plus the potential impacts on the environment, amenity and industry—there is a national interest in managing and containing the spread of *U. pinnatifida* to other jurisdictions. Management of aquaculture, small vessel movement, ballast water, biofouling, as well as management of current infested areas will be important in containing its spread.

Exotic species

Eriocheir sinensis (Chinese mitten crab)

Eriocheir sinensis is an invasive crab, native to Asia—China to the Korean Peninsula. It has successfully invaded temperate regions in central and northern Europe and North America (Naser et al. 2012). The wide temperature tolerances of *E. sinensis* (reproductive temperature range is 9 to 30 °C) indicate its potential range in Australia could be extensive. Sea surface temperature and temperature tolerances suggest the species could establish in New South Wales, Queensland, South Australia, Tasmania, Victoria and southern Western Australia (Richmond, Darbyshire & Summerson 2010).

In localities overseas where it has invaded, *E. sinensis* has had significant impacts in freshwater and brackish environments. These impacts include erosion in tidal marshes, collapse of stream banks, alteration of biogeochemical cycles, alteration of trophic interactions and food webs, competition with native estuarine crabs and freshwater crayfish and potential effects on prey items (Rudnick et al. 2005; Dittel & Epifanio 2009; as cited in Murphy & Paini 2010). *E. sinensis* also impacts infrastructure and industry including blocking of cooling systems of power plants as well as damage to local fisheries (including equipment damage and reduced catch), damage to agricultural crops such as rice and damage to irrigation channels (Dittel & Epifanio 2009 as cited in Murphy & Paini 2010). *E. sinensis* has the potential to harm human health, as it is an intermediate host for lung fluke and can bioaccumulate toxins and heavy metals (as cited in Murphy & Paini 2010).

The most common pathways of introduction of *E. sinensis* are commercial shipping (ballast water) or intentional introduction. This species was ranked as likely to be introduced to Botany Bay (Glasby & Lobb 2008) and Western Australia (Bridgwood & McDonald 2014) via commercial shipping (ballast water). Pathways need to be managed effectively to prevent the introduction of the species to Australia.

Rhithropanopeus harrisii ' (Harris' mud crab)

Rhithropanopeus harrisii is native to the Atlantic coast of the Americas from New Brunswick to northeast Brazil. It is a highly successful invader, having established in 20 countries across 45 degrees of latitude (Fowler et al. 2013). The main dispersal vector of *R. harrisii* is through ballast water (Harriet 2011). Dowell (2011) also notes that the species is likely to have first arrived in Europe via animal shipments for aquaculture or through hull fouling. The wide temperature tolerances of this species (optimum temperature range 15 to 25 °C, Hegele-Drywa & Normant 2014) suggest it could establish in Australia.

R. harrisii has a range of impacts that could potentially affect the environment, industry and infrastructure. For example, it is known to affect prey species richness and diversity negatively, altering prey population size structure (Forsstrom et al. 2015). In non-vegetated soft bottom sediments, it has been shown to modify taxonomic composition and species abundance of small benthic invertebrate communities in the Baltic Sea (Lokko et al. 2015). Anecdotal reports suggest that *R. harrisii* can alter food webs and displace native crabs, crayfish and bottom-feeding fish. It can also foul intake pipes, damage fish and gill nets—causing economic damage to fishers—and clog the cooling system in power plants (Keith 2007 in Roche & Torchin 2007; Zaitsev & Ozturk 2001 in Roche & Torchin 2007).

Due to the establishment potential of *R. harrisii* and the range of impacts on the environment, infrastructure and industry, pathways such as ballast water, aquaculture shipments and hull fouling need to be managed to prevent introduction.

Mytilopsis sallei (black-striped false mussel)

Mytilopsis sallei is an invasive mussel, native to the tropical central Atlantic Ocean—the Caribbean Sea—and has become established in Fiji, Indonesia, Singapore, Malaysia, Taiwan, India, China and West Africa. Its incursion into three Darwin marinas in 1999 was eradicated successfully (Bax et al. 2002). The potential range of *M. sallei* is determined by sea surface temperature, and temperature tolerance modelling suggest it could establish in marine waters of all jurisdictions in Australia (Richmond, Darbyshire & Summerson 2010).

M. sallei has serious impacts on biodiversity, by outcompeting and excluding native species and by modifying habitat through its dense settlement (Morton 1989; Subba Rao 2005; Lin & Yang 2006). *M. sallei* can have serious impacts on aquaculture facilities, with potential for massive fouling. This fouling can also have impact infrastructure such as wharves, sea water systems, buoys and vessels, causing a loss of amenity.

The primary vectors for the introduction of *M. sallei* include hull fouling, which was the pathway of introduction of the species to Darwin (Bax et al. 2002). It has also been detected on a number of foreign vessels entering Australia. These pathways need to be managed to prevent the introduction of *M. sallei* into Australian waters.

Perna canaliculus (New Zealand green-lipped mussel)

Perna canaliculus is native to New Zealand and is exotic to Australia. Its listing is precautionary based on the serious impacts that two of its congeners, *Perna perna* and *P. viridis*, have had wherever they have been introduced. It is a species of great economic importance in New Zealand as it is a significant industry there.

It has been predicted that *P. canaliculus* could establish in temperate areas of Australia, particularly south-eastern Australia, given the normal temperature tolerance of this species is between 10 °C and 19 °C (Ogilvie et al. 2004 as cited in Glasby & Lobb 2008). It is unlikely to survive in Sydney estuaries and further north when water temperatures are warmer (Glasby & Lobb 2008). There was a previous incursion of *P. canaliculus* in Adelaide and there have been numerous interceptions in Australian waters over the past 20 years (Wilkens & Allen 2015).

P. canaliculus has the capacity to outcompete native Australian blue mussels (*Mytilus galloprovincialis*) and the potential to cause significant impacts on mussel industries in Victoria and Tasmania (Murphy & Paini 2010; Richard Willan, pers. comm.).

Given previous interceptions of *P. canaliculus*, and potential for illegal spread due to the species' food value, the main pathways of hull fouling and human movement need to be managed to prevent the introduction of this species.

Perna perna (brown mussel)

Perna perna is an invasive mussel, native to tropical and subtropical waters of Africa and introduced to the north-western Indian Ocean, Gulf of Mexico, Caribbean Sea and southwestern Atlantic Ocean. This species has been recognised as a potential 'next pest' for Australia (Hayes & Sliwa 2003). The potential range of *P. perna* determined by sea surface temperature and temperature tolerance modelling suggest the species could establish in New South Wales, South Australia, Tasmania, Victoria and Western Australia (Richmond, Darbyshire & Summerson 2010).

P. perna forms dense aggregations, where densities of 27,200 individuals per square metre have been recorded (Murphy & Paini 2010). *P. perna* fouls navigation buoys—causing them to sink—as well as petroleum platforms, wrecks, jetties, rocky shores and other hard surfaces, increasing maintenance costs to remove fouling (Hicks & Tunnell 1995). It has also been known to damage water cooling systems of power plants located in the Gulf of Mexico (GISD 2017i). *P. perna* may impact human health due to bioaccumulation of heavy metals and has been documented to harbor saxitoxin from consumed dinoflagellates, with its consumption being linked to outbreaks of paralytic shellfish poisoning in Venezuela (Barbera-Sanchez et al. 2004).

The primary vector for the spread of *P. perna* is hull fouling; ballast water and the translocation of fish and shellfish also have the potential to spread this species.

Perna viridis (Asian green mussel)

Perna viridis is an invasive mussel, native to the Arabian Sea, China, India, Thailand, Malaysia and the Philippines. It has been introduced accidentally and/or deliberately to the United States and Caribbean Sea, tropical South America (Venezuela), Japan and South Africa. It is currently exotic to Australia and has been recognised as a potential 'next pest' for Australia (Hayes & Sliwa 2003). Its potential range as determined by sea surface temperature and temperature tolerances suggest the species could establish in Queensland, Northern Territory, Western Australia and New South Wales (Richmond, Darbyshire & Summerson 2010).

The primary vectors of *P. viridis* are hull fouling and ballast water. There are numerous instances of *P. viridis* arriving in Australian waters on vessel hulls and barges from South-East Asia, sometimes in the thousands (Richard Willan [APMPL task group] pers. comm.).

In its introduced range, the impacts of *P. viridis* include altered biodiversity by outcompeting or overgrowing native species, changes in community structure and trophic relationships and habitat modification (formation of reefs on soft sediments) (Baker & Benson 2002; Boudreaux & Walters 2006; McFarland, Donaghy & Volety 2013; Spinuzzi et al. 2013; Csurhes 2015). *P. viridis* also has an impact on marine infrastructure and the economy, fouling vessels, wharves, buoys, power stations and mariculture equipment; populations have been recorded with up to 35,000 individuals per square metre weighing approximately 72 kilograms (Morton 1996; Murphy & Paini 2010; Csurhes 2015). There is a potential human health risk if it is consumed as it accumulates heavy metals and can contain a potent toxin called saxitoxin. Saxitoxin is a toxin produced by certain dinoflagellates upon which it feeds (Csurhes 2015).

Given the potential impacts of *P. viridis* and its establishment potential in Australia, pathways of hull fouling and ballast water need to be managed to prevent its introduction.

Species to review

In addition to the recommended listed species, the task group identified species to reconsider when more information becomes available. These species are:

Exotic

- *Sargassum horneri* (brown macroalga)—has only been found outside of its native range in one location (California) and control has not been attempted. There is limited information about this species.
- *Charybdis japonica* (Asian paddle crab)—there is limited information about the impacts of this species.
- *Hemigrapsus takanoi* (Takano's shore crab)—there is limited information on this species.

Established

- *Petrolisthes elongatus* (New Zealand porcelain crab)—there is limited information on the impacts of this species.

Conclusions

The Australian Priority Marine Pest List task group brought together a range of experts on marine pests across Australia, including taxonomic, policy, operational and technical experts. This expertise provided a solid foundation to critically assess the multitude of candidate marine pests against the policy requirements (NEBRA and EPDNS) to determine a recommended list of Australia's priority marine pests.

The task group has recommended nine species for consideration by the MPSC for the APMPL, three established and six exotic species. These comprise one alga (*Undaria pinnatifida*); three crabs (*Carcinus maenas*, *Eriocheir sinensis* and *Rhithropanopeus harrisii*); four molluscs (*Mytilopsis sallei*, *Perna canaliculus*, *Perna perna* and *Perna viridis*) and one echinoderm (*Asterias amurensis*). The final list of nine marine pests is a highly refined and considered subset of the original 167 candidate species. These nine marine pests are those that were assessed by the task group to meet the assessment framework criteria, which were based on two overarching government policies—the NEBRA for exotic pests and the EPDNS framework for established species. The task group recommended an additional four species for review when further information on their impacts, identification and/or control becomes available.

The species listed on the APMPL are those that have been assessed as having the potential to have significant environmental, economic or social impacts in Australia should they arrive, or, in the case of established pests, there is a national interest to limit their spread and manage impacts within Australia. For the listed species, and indeed any marine pests, the key message is one of prevention and preparedness. The introduction of marine pests into Australia is largely through vectors such as shipping and recreational craft, primarily via ballast water and hull fouling. Within Australia, a marine pest may further spread through these same vectors as well as hitchhiking on fishing equipment, through the movement of aquaculture stock and via natural dispersal. Prevention measures are aimed at reducing the risk of introduction and spread to ensure that the impacts of marine pests are minimised. Preventing the spread of marine pests may take many forms. This includes adherence to the ballast water regulations in line with the IMO's ballast water convention (ballast water exchange or treatment), application of anti-fouling paint and practices to minimise biofouling on hull and niches in accordance with the IMO's biofouling guidelines and the prevention of the import of live organisms through the live import regulations. Prevention measures are usually not species specific and may apply to a broad range of marine species. Therefore, preventing the introduction and spread of species listed on the APMPL should also reduce the likelihood that other marine pests are introduced.

Prevention measures are crucial as some of the candidate marine pests have the potential to have significant impacts on Australia's environment should they arrive. However, not all of these species have been recommended for the APMPL as some failed to meet particular listing criteria. For example, expert opinion was that the exotic common acorn barnacle (*Balanus glandula*) could not be identified or distinguished from native barnacles in the field, particularly from the native six-plated barnacle *Chthamalus antennatus*. For exotic species, to meet the NEBRA criteria, control options must also be available to manage marine pests, with the aim of eradication, should they arrive. For some marine pests, no control options are available that could be employed to eradicate the pests or control their numbers should there be an incursion. In these cases, prevention measures are the only defence against the impacts of these marine pests on Australia's environment.

Recommendations for the assessment framework

The assessment framework developed by the task group has provided a basis to assess a number of species in a transparent, defensible and relatively straightforward manner. The MPSC has indicated that the APMPL should be reviewed every two years. ABARES has several recommendations that have been agreed with the task group, which should be considered for future refinement of the assessment framework. These refinements would assist future assessors to ensure consistency and limit subjectivity between assessments.

Development of a guidance document

Gathering information to support the species assessments and assisting in decision making takes time and resources. To help streamline the process, limit subjectivity and to ensure consistency within responses for each criterion, it is suggested that a short guidance document be developed and made available to assessors. This would ensure that the context of each criterion is understood by each assessor, and would frame the situation so that consistency is maintained between different assessors and between re-assessments. Appendix D (tables D1 to D3) provides some guidance that could be built upon.

For example, criterion 1F (Table D1) deals with vectors and natural pathways. This was one of the most difficult criteria for assessors to answer. Specific guidance on why vectors are being considered would assist in interpretation of the question (for example, management response and intervention measures).

Another example is criterion 1E (Table D1), control in the environment. Specific guidance could be provided to help assessors understand the intended outcomes of the criterion. The core question to be answered is whether control measures exist for the particular species and whether they have been applied successfully. However, the intended outcome of control was not clear. For example, differentiating whether the criterion relates to the availability of control techniques for managing species numbers versus availability of control techniques with the outcome of eradicating the species.

Relocation of one criterion

For an established species to be assessed as a priority marine pest, it must be agreed that there is national interest in containing its spread and improving its management. This criterion is currently placed in Step 1 'Stop/go' criteria (1J). However, in order to answer this criterion, there must be an understanding of the impacts of the species (Step 2). Moving the national interest criterion to the end of Step 2, would ensure that all aspects of its biology and impacts could be understood fully to make an informed decision about whether there would be a national interest in limiting its spread.

Potential future actions

The listing of species enables a clear focus point on marine pests. These significant marine pests can aid in fostering national improvements in marine pest communication, surveillance, preparedness (including incursion response) and ongoing management. The nine species recommended for the APMPL consist of three established and six exotic species. The task group proposes a number of actions for the APMPL species for consideration by the MPSC (Table 1). The development of an implementation plan on how the APMPL will be used to guide these future actions, communication and research will be important next steps for the MPSC.

Table 1 Potential actions for Australian Priority Marine Pest List species

Action type	Exotic priority species	Established priority species
Preparedness	Incursion preparedness	National management plan
Legislative	Declared noxious in each state/territory	Declared noxious in each state/territory
Surveillance	Passive and active surveillance for species	Passive and active surveillance for species
Reporting	Report any detection	Report significant range extensions
Response and management	Incursion response	Contain national spread
Awareness	National awareness activities	National awareness activities
Research priorities	Research priorities such as prevention, diagnostics, and impact mitigation.	Research priorities such as prevention, diagnostics, and impact mitigation.

Appendix A: APMPL listing criteria

Version approved by MPSC 08 (23 September 2014) and NBC Out-of-Session (May 2015).

Background

The Australian Priority Marine Pest List (APMPL) is a list of marine pests, some exotic to Australia and some established in parts of Australia, which forms the basis of Australia's reporting system for marine pests.

Australia's states and territories report detections of listed national priority marine pest species to the Consultative Committee on Introduced Marine Pest Emergencies (CCIMPE) in line with the reporting requirements outlined in the National Environmental Biosecurity Response Agreement (NEBRA). This information is used to inform response activities, and update the National Introduced Marine Pest Information System (NIMPIS) and the ballast-water risk tables.

The Marine Pest Sectoral Committee (MPSC) is implementing the National System for the Prevention and Management of Marine Pest Incursions (the National System), which includes prevention, emergency management and ongoing management and control activities. MPSC is the owner of the APMPL and decides the content of the APMPL.

Purpose of the APMPL

The APMPL creates a mechanism for reporting detections of marine pests of national priority. It also facilitates a nationally coordinated series of actions for listed marine pests and signals to stakeholders how governments might respond to those listed marine pests.

When a pest that is on the APMPL for the purpose of reporting is detected, reports will be made to CCIMPE, and the secretariat of CCIMPE will collate these data for dissemination to relevant government jurisdictional representatives of CCIMPE.

Reporting on the marine pests on the APMPL may also:

- ensure national awareness of the marine pests of concern of each state/territory
- support inter-state and intra-state management where appropriate
- support interstate movement, zoning and translocation policies
- inform the further development of diagnostic tests, surveillance and response protocols to meet the needs of Australian marine industries
- support applications for cost shared emergency response activities made in accordance with the NEBRA
- provide a reference to allow government and stakeholders to consider factors that may:
    - affect negotiations in trade
    - guide national and international assessment of species-based marine pest free 'zones'.

Listing criteria for the APMPL

For an exotic marine species to be listed on the APMPL as a marine pest, the species must:

- meet the national significance criteria outlined in the NEBRA (in the absence of published scientific data on the potential impacts of exotic species, a scientific reference group may be formed to provide expert advice to fill any missing data)
- be able to be clearly described and able to be readily and rapidly identified.

For an established marine pest to be listed on the APMPL, the species must:

- have (or be likely to have) a significant national impact (see section Development of the Assessment Framework, Step 2 Impacts)
- be able to be managed in ways that are feasible (see section Development of the Assessment Framework, Step 2 Impacts)
  - if management of an established pest is not considered feasible, but the significant national impact of the pest is assessed as high, the pest may be listed for the purpose of coordinated research and development, national awareness and communication activities, or monitoring
- benefit from national coordination in the management and control measures necessary to minimise its spread.

For a species to be removed from the APMPL, the species must no longer qualify for one of these criteria.

Alteration strategy

The APMPL is to be reviewed under the oversight of the MPSC with input of technical expertise provided by CCIMPE.

The APMPL will be reviewed biennially by MPSC and on an ad hoc basis, with the agreement of MPSC, to allow marine pests of concern to be added or deleted at any time. Recommendations for addition or deletion can be made by relevant technical experts and endorsed by MPSC. Any deletion from the APMPL must not interfere with regional reporting requirements.

Taxa on the APMPL can have their scientific names updated at any time upon the recommendation of a specialist taxonomist, but any such change must be based on a published revision, and endorsed by MPSC.

During the biennial review of the APMPL it will be a requirement to justify why each established marine pest remains on the APMPL. It is not feasible for the APMPL to grow in perpetuity.

APMPL glossary

Table A1 Terms used in the Australian Priority Marine Pest List

Term	Definition
Benefit from national coordination (established pest)	There must be a clearly demonstrable benefit from a nationally coordinated approach or 'plan' that outlines the action to be undertaken by all responsible parties. An established pest may have (or potentially have), significant impacts in one or more regions, but would not be considered as an established pest of national significance if no particular benefit can be demonstrated by taking a nationally coordinated approach, or having a national plan. An example where national coordination would be of benefit would be where regional containment is desirable and nationally consistent and coordinated 'movement controls' are required for that purpose. Another example may be where there is Commonwealth/national or shared funding available that can be invested in an agreed and coordinated fashion. It should be noted that a national plan or approach does not necessarily mean a plan of government action.
Established pest	A self-sustaining pest that occurs in Australia and is not regarded as eradicable. An established pest may be distributed widely across Australia, or be only regionally distributed. A regionally-distributed established pest may be the subject of containment measures to mitigate further spread. Native or indigenous plants and animals are not characterised as established pests for the purposes of this framework (even if having negative impacts).
Exotic species	A species that is not established in Australia.
Feasible to manage (established pest)	Factors to consider in assessing the feasibility of managing the established pest include: • technical feasibility of implementing a management approach • potential role of regulatory mechanisms • cost-effectiveness of the proposed approach • level of socio-political support.
National impact (established pest)	National impact in the context of an exotic marine pest refers to impacts on one or more of the following: • international market access and/or trade • the economic health of the nation • human health • the natural environment and ecosystems • infrastructure causing disruption to more than one state/territory • substantial damage to, or deterioration of infrastructure used by a significant proportion of people over an extensive area • amenity of resources, such as public lands, and that has the potential to affect more than one state/territory Australian culture, cultural assets, practice or custom or national image.

Note: Definitions are derived from the Established Pests and Diseases of National Significance framework.

Appendix B: APMPL terms of reference

Version approved by MPSC Out-of-Session (March 2015).

Purpose

The purpose of the Australian Priority Marine Pest List task group (the task group) is to populate the Australian Priority Marine Pest List as per the criteria agreed by the Marine Pest Sectoral Committee (MPSC 08).

The Australian Priority Marine Pest List (APMPL) will be a list of marine pests, some exotic to Australia and some established in parts of Australia, which forms the basis of Australia's reporting system for marine pests. The APMPL creates a mechanism for reporting detections of marine pests of national priority. It also facilitates a nationally coordinated series of actions for listed marine pests and signals to stakeholders how government might respond to those listed marine pests.

Background

Appendix A provides the listing criteria agreed by the Marine Pest Sectoral Committee (MPSC 08).

In effect, there will be two sub-lists:

1) Exotic marine species that are not known to be established in Australia, that have potential for nationally significant impacts and would be candidates for a national incursion response (if technically feasible and cost-beneficial) under the National Environmental Biosecurity Response Agreement (NEBRA). Such listing does not exclude other species from NEBRA consideration, but rather provides a focus for improving national prevention, detection and preparedness.
2) Established marine pests of national significance for which there are feasible and beneficial management actions to minimise their spread that require a nationally coordinated approach (including containment, control, R&D, communication and/or monitoring).

In populating the APMPL, the task group will take account of national policy directions, in particular the Intergovernmental Agreement on Biosecurity and associated documents. These include:

- NEBRA (under which the Consultative Committee on Introduced Marine Pest Emergencies [CCIMPE] operates)
- Framework for Management of Established Pests and Diseases of National Significance (EPDNS)
- National Surveillance and Diagnostics Framework.

The task group will also take account of the National System for the Prevention and Management of Marine Pest Incursions.

Scope

Operating in a manner consistent with the MPSC terms of reference, the task group will take a standard risk management approach to populating the APMPL by:

- workshopping/liaising with MPSC and CCIMPE to describe the current and future national policy, legislative and operational context in which the list would be applied (this step is needed to indicate the likely feasible size of the list and the depth of analysis required)
- proposing an assessment methodology to MPSC to assess species' marine pest risk (of introduction, establishment, spread and impact) and the feasibility of managing such risks
- compiling a list of candidate species for consideration, initial screening and further assessment
- undertaking these risk and feasibility assessments
- making recommendations to MPSC on the inaugural version of the APMPL, in consultation with CCIMPE.

Throughout this process, the task group will provide support and advice to MPSC on its communication and consultation with stakeholders (including government, industry and community) on the list process and outcomes.

Membership

Task group members are expected to:

- have operational, scientific and/or policy responsibilities reflecting the work of the task group
- have approval of their host organisations to actively participate in task group activities, including funding costs of any face to face task group workshops required to populate the APMPL
- undertake tasks allocated to them out of session to progress achievement of task group milestones
- consider a range of views in making decisions, including jurisdictional, organisational, nationally strategic, operational and scientific.

The Chair is expected to:

- organise meetings/teleconferences of task group and subsequently circulate minutes
- circulate documents of relevance for out of session comment and coordinate responses
- draft MPSC agenda papers and submit to the MPSC secretariat pending task group approval.

Reporting

The task group will report directly to and take instructions from the MPSC.

Timeframe and resources

This will be detailed in a whole of project work plan, to be put to MPSC for endorsement following the first workshop.

Meetings and meeting venue

Meetings will be held in person—or via teleconference where required—and iterative work will be undertaken via email.

Appendix C: APMPL expert contributors

Table C1 Task group members and technical experts assisting the development of the APMPL

Name	Organisation	Membership
Shane Ahyong	Australian Museum	Technical expert
Victoria Aitken	Department of Fisheries Western Australia	Task group
Heidi Alleway	Primary Industries & Regions South Australia (PIRSA)	Task group
John Barker	Victorian Department of Environment, Land, Water & Planning	Task group
Murray Barton	Northern Territory Department of Primary Industry and Fisheries	Task group
Michelle Besley	Primary Industries & Regions South Australia (PIRSA)	Task group
Alex Chalupa	Primary Industries & Regions South Australia (PIRSA)	Task group
Ashley Coutts	Biofouling Solutions Pty Ltd	Task group
Marty Deveney	South Australian Research & Development Institute (SARDI)	Task group
Sridevi Embar Gopinath	Australian Government Department of Agriculture and Water Resources	Task group
Ingo Ernst	Australian Government Department of Agriculture and Water Resources	Technical expert
Chris Glasby	Museum and Art Gallery of the Northern Territory	Technical expert
Tim Glasby	Fisheries NSW (NSW DPI)	Task group
Sonia Gorgula	Australian Government Department of Agriculture and Water Resources (and Primary Industries & Regions SA)	Task group
Sarah Graham	Australian Government Department of Agriculture and Water Resources	Task group
Charles Griffiths	University of Cape Town	Technical expert
Kylie Higgins	Australian Government Department of Agriculture and Water Resources	Task group
Diana Jones	Western Australian Museum	Technical expert
John Lewis	ES Link Services Pty Ltd	Task group
Pat Lewis	Biofouling Solutions Pty Ltd	Task group
Alicia McArdle	Australian Government Department of Agriculture and Water Resources	Task group
Justin McDonald	Department of Fisheries Western Australia	Task group
Dean Paini	CSIRO	Technical expert
Robert Parker	Queensland Department of Agriculture and Fisheries	Task group
Sandra Parsons	Australian Bureau of Agricultural and Resource Economics and Sciences (Department of Agriculture and Water Resources)	Task group
Anita Ramage	Queensland Department of Agriculture and Fisheries	Task group
Ben Rampano	Fisheries NSW (NSW DPI)	Task group
Tim Riding	NZ Ministry for Primary Industries/Manatū Ahu Matua	Task group
Jeff Ross	University of Tasmania	Technical expert
Michael Sierp (Chair)	Primary Industries & Regions South Australia (PIRSA)	Task group
John Virtue (Chair)	Primary Industries & Regions South Australia (PIRSA)	Task group
Lexie Walker	Australian Museum	Technical expert

Name	Organisation	Membership
Melissa Walker	Fisheries NSW (NSW DPI)	Task group
Richard Willan	Museum and Art Gallery Northern Territory	Task group
Robin Wilson	Museum Victoria	Technical expert
Jeff Wright	University of Tasmania	Technical expert

Appendix D: APMPL assessment criteria

Table D1 Step 1 Stop/go criteria for established and exotic species

Criterion code	Criterion	Explanatory information
1A	The species is not freshwater for the whole of its life[a].	Species are considered freshwater where reproduction only occurs in freshwater environments. For species with wide salinity tolerances, inclusion on the list will primarily depend on where the majority of their impacts occur.
1B	The species is not native.	Species that are native to Australia are not considered further in the assessment. Uncertainty over a species' native range may preclude a species from being assessed further.
1C	The species is not on the EPBC Act live import list.	The EPBC Act live import list must be reviewed for each species to confirm its import status. Species allowed for live import are not considered further because repeated introductions are legally permissible.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	The listing criteria states that species must be identifiable. This test has two parts that must be met: • the taxonomic certainty of the species must be resolved • the species must be identifiable from natives in the field in at least one stage of its lifecycle, without the use of molecular methods.
1E	The species could feasibly be controlled in the environment.	Are there methods available that could feasibly control an incursion of the species in a harbour environment (in contrast to open ocean)? If eradication or control would not be feasible for logistical or technical reasons, (for example, the species is microscopic, highly mobile or uncontainable) then a species may be rated as difficult to control. For established pests, this criterion applies to a new incursion in a new jurisdiction.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	In an incursion scenario, an assessment is required of the feasibility to manage both anthropogenic vectors of spread and natural dispersal. Anthropogenic vectors include shipping, non-commercial shipping, fishing vessels, recreational vectors, translocation of aquaculture stock and fishing vessels equipment. The biology of the species is to be considered for management of spread by natural means.
2	The species progresses to Step 2.	If the species meets all criteria for Step 1 (including additional exotic species or established species criteria in Table D2 and Table D3) it progresses to Step 2 of the assessment process where its impacts are determined. If the species fails to meet one of the Step 1 criteria, it is eliminated form further consideration.

a Freshwater species will be referred to the Invasive Plants and Animals Committee (IPAC) freshwater fish expert group.

Table D2 Step 1 Stop/go screening, additional criteria for exotic species

Criterion code	Criterion	Explanatory information
1G	The species is not known to be present in Australian waters	This criterion examines the native and introduced range to confirm the species status in Australia. Species that are present but not native—which have been introduced to Australia—are considered 'established', and are assessed with the criteria in Table D3.
1H	The species could feasibly be transported to Australia via an anthropogenic vector	Anthropogenic vectors include commercial shipping, non-commercial shipping (such as research, naval and harbour management vessels) and fishing and recreational vessels. Consideration may also be given to the movement of species as 'hitchhikers' such as on diving equipment. Aquaculture movements are not included, due to Australian biosecurity regulations restricting the import of aquaculture stock.
1I	The species has the potential to become established in Australian waters	The environmental tolerances of a species restricts its ability to establish in new jurisdictions. These are determined by comparison of the environmental conditions in the species native and introduced range compared with that of Australia.

Table D3 Step 1 Stop/go screening, additional criteria for established species

Criterion code	Criterion	Explanatory information
1J	There is likely to be national interest in containing the species' spread and improving its management	na
1K	There are populations established in the wild in Australia that are not feasible to eradicate	This criterion is to confirm the species is an established species, beyond a NEBRA incursion response.
1L	The species is not widely cultivated in Australia	If a species is only subjected to wild harvest, it is determined not to be 'widely cultivated'.
1M	The species is not established in all potential jurisdictions (to the best of knowledge)	Maps of potential distribution for established pests should be available. A species is deemed not to have established in a jurisdiction if there is only a record of a single individual in the wild, or if individuals have only been recorded from visiting vessels in that jurisdiction. Species that have established in all jurisdictions in which it could theoretically occur are deemed not to require further management responses at a national level to prevent their spread.
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal	If a species' main pathway of spread is via natural dispersal, then the prevention of spread by management of anthropogenic means will unlikely curb its movement to new jurisdictions.

na No additional information.

Table D4 Step 2 Impacts criteria

Category code	Impact category	Criterion
2-0	Impact intensity (prerequisite)	The species is likely to reach high densities and maintain its invasiveness over time.
2A	Environmental impacts[a]	The species impacts the physical environment, biodiversity, ecological structure or function, or ecosystem services.
		The species is likely to lead to the extinction or significant decline of a nationally protected or endangered species or community[b].
		The species impacts ecologically valuable marine species[c].
		The species impacts places of nationally importance (relevant to the national identity)[a].
		The species impacts an ecologically valuable places[d].
2B	Social impacts[e]	The species impacts infrastructure used by a significant proportion of people.
		The species impacts amenity of resources used by a significant proportion of people over and extensive area.
		The species impacts cultural assets valued by particular sections of the community.
2C	Business impacts[e]	The species impacts the profitability of recreational or commercial fisheries (including aquaculture).
		The species impacts the profitability of any other industry directly reliant on utilisation of and/or access to the marine environment.
		The species impacts product acceptability in international markets and/or state/territory access to domestic markets.
		The species impacts international and/or domestic shipping due to increased costs of meeting required biosecurity standards.
2D	Human health impacts	The species is likely to cause illness and/or physical injury to people resulting in deaths, permanent disabilities and/or substantial long-term health costs to the community.
3	Response	The species progress to Step 3[f], and recommendation for the APMPL.

a Relevant impacts are those that are considered to be significant negative consequences, over and above those that occur due to native species. **b** Protected marine species and communities are listed in the Environment Protection and Biodiversity Act 1999. **c** Ecologically valuable marine species include keystone marine species, such as kelp forests, seagrasses, and mangroves. **d** The Great Barrier Reef is an example of a nationally important place. **e** RAMSAR-listed wetlands are examples of ecologically valuable places. **f** Relevant impacts are significant negative social or business consequences, relating to those that might seriously disrupt current usage, practices or profitability. In terms of financial costs, significant negative consequences of a pest once it became widely established would be in the order of greater than $10 million per annum in terms of impacts and the pest’s management. **g** Unlike for Step 1, all criteria are not required to be true for a species to progress to the next step, if applicable impacts are deemed suitably significant.
The Environment Protection and Biodiversity Act 1999 contains a full list of protected areas and species.

Table D5 Step 3 Control and management criteria

Criterion code	Criterion	Explanatory information
3A	There is a national control plan for the species.	If there is no current control plan, provide details of known control options for the pest.
3B	There are molecular tools for identifying the species.	na
3C	The potential distribution of the species has been modelled.	A temperature-based distribution model will be required to inform management and cost-sharing arrangements

na No additional information.

Appendix E: APMPL referenced marine pest lists

Australian and New Zealand marine pest lists

Table E1 Marine pest lists consulted by APMPL task group

Marine pest list	List details	No. of marine species on list
CCIMPE trigger list	A list of species largely based on the work by Hayes & Sliwa (2003) and Hayes et al. (2005). It includes species exotic to Australia, species established in Australia but not widespread and holoplankton alert species. This list is no longer active, but is still commonly referenced.	35
CCIMPE watch/notification list	An additional eight species are on the CCIMPE watch/notification list.	8
Marine ballast water decision support system (DSS)	This is based on the ballast water risk assessment framework developed by CSIRO Marine Research (CMR), which includes species established in Australia that may be transferred from one Australian port to another Australian port via ballast water (Hayes et al. 2004)	7
Marine pest monitoring target species list	The monitoring list of target species is listed in the Australian marine pest monitoring guidelines. These are species that have been identified as high risk for Australia as a whole, based on their invasion and impact potential, and human health impacts (Department of Agriculture and Water Resources 2010). The list includes: • species for which ballast water management is required (currently seven species) • species on the priority pest list (domestic) in Hayes et al. (2005), that are ranked as a high or medium priority for management; or low priority with a human health impact • species on the next pest list (international) in Hayes et al. (2005) that are ranked as a high or medium priority for management; or low priority with a human health impact • species on the trigger list of introduced marine pests used in emergency management by the CCIMPE.	55
Species of biofouling concern list	A list of species that have been determined by risk assessment to have a high probability of arrival to Australia, with the potential to cause moderate to extreme impacts on the environment, economy, social/cultural values and/or human health (Hewitt et al. 2011). This list was developed under previous legislative frameworks (*Quarantine Act 1908), but with the introduction of the Biosecurity Act 2015 is no longer part of current national policy.*	56
NIMPIS list	A central repository of information on invasive marine pest species, including species introduced and exotic to Australia (NIMPIS 2009).	100+
State and territory lists	Western Australian—the Western Australian prevention list for introduced marine species (Western Australian Department of Primary Industries and Regional Development 2016).	76
	Northern Territory—the list of noxious species (Northern Territory Government 2018).	44

Marine pest list	List details	No. of marine species on list
	Queensland—the Biosecurity Act 2014 (Schedule 1, Part 5) lists prohibited species of marine animals and plants (Queensland Department of Agriculture and Fisheries 2017)	33
	New South Wales—prohibited matter, including marine pests, is listed in the Biosecurity Act 2015 (Schedule 2) (Department for Planning and Spaces 2018).	40
	Victoria—the list of declared noxious aquatic species in Victoria (marine and freshwater) (Victorian Fisheries Authority 2010) as determined under section 75 of the *Fisheries Act 1995.*	5
	Tasmania—six species are declared as key marine pests in Tasmania.	6
	South Australia—noxious fish list: marine pests (PIRSA 2019) as declared under the *Fisheries Management Act 2007*.	29
New Zealand Surveillance list	The New Zealand Port Surveillance list contains two parts:	
	• species not established in the country	5
	• established species that are geographically restricted.	4

Note: The number and species on each list is accurate as of 2016, when species selections were undertaken. The lists and species' status may have been updated since then.

Candidate species reference sources

Table E2 Candidate species list for *Algae (Chlorophyta)*

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Avrainvillea amadelpha (Leather mudweed)	–	–	X	–	–	–	–	–	Initial screening—low impact (biofouling risk assessment)
Caulerpa filiformis (Green macroalga)	–	–	–	–	–	–	X	–	Initial screening—moderate impact (CCIMPE review)
Caulerpa cylindracea (Grape algae)	–	–	X	–	–	–	–	–	Step 1 (1B)—species is native
Caulerpa taxifolia (Aquarium weed)	Trigger list: exotic	–	X	–	All	Exotic	X	–	Step 1 (1B, 1D)—species is native and not readily identifiable in the field
Codium fragile atlanticum (Green sea fingers)	–	–	–	X	–	–	–	–	Initial screening—low impact (biofouling risk assessment)
Codium fragile (Broccoli weed)	Trigger list: established	–	X	–	NT, Qld, NSW, SA, WA	–	–	–	Step 1 (1D, 1E)—species is not readily identifiable in the field and cannot feasibly be controlled in the environment
Ulva fasciata (Sea lettuce)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Ulva australis [syn. *Ulva pertusa*] (Sea lettuce)	–	–	–	X	–	–	X	–	Step 1 (1B, 1D)—species is native and not readily identifiable in the field

X Species on list.

Note: Steps for assessing each species are listed in Appendix D. Impact assessment during initial screening was according to CCIMPE *Review: Update 2007–2009* (Murphy & Paini 2010) and *Species Biofouling Risk Assessment* (Hewitt et al. 2011).

Table E3 Candidate species list: *Algae (Miozoa)*

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Alexandrium monilatum (Toxic dinoflagellate)	Trigger list: holoplankton exotic	–	X	–	NT, Qld, WA	–	–	–	Step 1 (1E)—species cannot feasibly be controlled in the environment
Alexandrium spp. (*A. catenella, A. minutum, A. tamarense*) (Toxic dinoflagellate)	–	–	X	–	WA	–	X	–	Step 1 (1E)—species cannot feasibly be controlled in the environment
Dinophysis norvegica (Toxic dinoflagellate)	Trigger list: holoplankton exotic	–	X	–	NT, WA	–	–	–	Step 1 (1E)—species cannot feasibly be controlled in the environment
Gymnodinium catenatum (Toxic dinoflagellate)	–	–	X	–	WA	–	–	–	Step 1 (1E)—species cannot feasibly be controlled in the environment
Pfiesteria piscicida (Toxlc dinoflagellate)	Trigger list: holoplankton exotic	–	X	–	NT, Qld, WA	–	–	–	Step 1 (1E)—species cannot feasibly be controlled in the environment

X Species on list.

Note: Steps for assessing each species are listed in Appendix D.

Table E4 Candidate species list: *Algae (Ochrophyta)*

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Chaetoceros concavicornis (Centric diatom)	Trigger list: holoplankton exotic	–	X	–	NT, Qld, WA	–	–	–	Step 1 (1E)—species cannot feasibly be controlled in the environment
Chaetoceros convolutus (Centric diatom)	Trigger list: holoplankton exotic	–	X	–	NT, Qld, WA	–	–	–	Step 1 1E—cannot feasibly be controlled in the environment)
Chattonella antiqua (Raphidophyte)	–	–	–	X	–	–	–	–	Step 1 (1E)—species cannot feasibly be controlled in the environment
Corethron pennatum [syn. *Corethron criophilum*] (Centric diatom)	–	–	–	X	–	–	–	–	Step 1 (1E)—species cannot feasibly be controlled in the environment
Fucus evanescens (Brown alga)	–	–	–	X	WA	–	–	–	Initial screening—low impact (biofouling risk assessment)
Pseudochattonella farcimen (Raphidophyte)	–	–	–	X	–	–	–	–	Step 1 (1D, 1E)—species is not readily identifiable in the field and cannot feasibly be controlled in the environment
Pseudo-nitzschia seriata (Pennate diatom)	Trigger list: holoplankton exotic		X	X	NT, Qld, WA	–	–	–	Step 1 (1E)—species cannot feasibly be controlled in the environment
Sargassum horneri (Horner’s sargassum)	–	–	–	–	–	–	–	Tim Glasby	Step 1 (1D, 1E)—species is not readily identifiable in the field and cannot feasibly be controlled in the environment
Sargassum muticum (Wireweed)	Trigger list: exotic		X	X	NT, Qld, NSW, SA, WA	–	–	–	Step 1 (1D, 1E)—species is not readily identifiable in the field

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
									and cannot feasibly be controlled in the environment
Undaria pinnatifida (Asian kelp)	Trigger list: established	X	X	–	All	–	X	–	Recommended for APMPL

X Species on list.

Note: Steps for assessing each species are listed in Appendix D. Impact assessment during initial screening was according to CCIMPE *Review: Update 2007–2009* (Murphy & Paini 2010) and *Species Biofouling Risk Assessment* (Hewitt et al. 2011).

Table E5 Candidate species list: *Algae (Rhodophyta)*

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Bonnemaisonia hamifera (Bonnemaison's hook weed)	–	–	X	–	WA	–	–	–	Initial screening—low impact (CCIMPE review)
Gracilaria vermiculophylla (Red macroalga)	–	–	–	–	–	–	–	John Lewis	Step 1 (1D, 1E, 1F)—species is not readily identifiable in the field, cannot feasibly be controlled in the environment, and pathways and vectors cannot feasibly be managed
Grateloupia imbricate (Forked Grateloup's weed)	–	–	–	–	–	–	–	John Lewis	Step 1 (1J, 1K)—there is likely no national interest in species management, and established populations in Australia are not feasible to eradicate
Grateloupia turuturu (Devil's tongue weed)	Trigger list: established	–	X	–	NT, Qld, NSW, SA, WA	–	X	–	Step 1 (1D, 1E, 1F)—species is not readily identifiable in the field, cannot feasibly be

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
									controlled in the environment, and pathways and vectors cannot feasibly be managed
Polysiphonia brodiei (Brodie's siphon weed)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Schizymenia apoda (Red macroalga)	–	–	–	–	–	–	–	John Lewis	Step 1 (1D, 1E, 1F)—species is not readily identifiable in the field, cannot feasibly be controlled in the environment, and pathways and vectors cannot feasibly be managed
Womersleyella setacea (Red macroalga)	–	–	X	–	–	–	–	–	Initial screening—low impact (CCIMPE review)

X Species on list.

Note: Steps for assessing each species are listed in Appendix D. Impact assessment during initial screening was according to CCIMPE *Review: Update 2007–2009* (Murphy & Paini 2010) and *Species Biofouling Risk Assessment* (Hewitt et al. 2011).

Table E6 Candidate species list: *Annelida*

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Alitta succinea (Pile worm)	Watch list	–	–	–	NT, NSW	–	X	–	Initial screening—low impact (CCIMPE review)
Boccardia proboscidea (Spionid polychaete worm)	Watch list	–	–	–	NT, NSW	–	–	–	Initial screening—low impact (CCIMPE review)

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Euchone limnicola (Sabellid polychaete worm)	Watch list	–	–	–	NT, NSW	–	X	–	Initial screening—low impact (CCIMPE review)
Hydroides dianthus (Serpulid tubeworm)	–	–	X	X	WA	–	–	–	Initial screening—low impact (CCIMPE review)
Hydroides elegans (Fouling serpulid tubeworm)	–	–	–	–	–	–	X	–	Step 1 (1D)—species is not readily identifiable in the field
Marenzelleria spp. (Red-gilled mudworm)	Trigger list: exotic	–	X	–	NT, Qld, NSW, SA, WA	–	X	–	Step 1 (1D)—species is not readily identifiable in the field
Myxicola infundibulum (Slimy featherduster worm)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Polydora ciliata (Spionid polychaete worm)	–	–	–	–	–	–	X	–	Step 1 (1D)—species is not readily identifiable in the field
Polydora cornuta (Spionid polychaete worm)	Watch list	–	–	–	NT, NSW	–	–	–	Step 1 (1D, 1E)—species is not readily identifiable in the field and cannot feasibly be controlled in the environment
Polydora nuchalis (Spionid polychaete worm)	–	–	–	X	–	–	–	–	Step 1 (1D)—species is not readily identifiable in the field
Polydora websteri (Spionid polychaete worm)	Watch list	–	–	–	NT, NSW	–	–	–	Step 1 (1D, 1E)—species is not readily identifiable in the field and cannot feasibly be controlled in the environment
Pseudopolydora paucibranchiata	–	–	–	–	–	–	X	Lexi Walker	Initial screening—low impact (CCIMPE review)

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
(Japanese polydroid worm)									
Sabella spallanzanii (European fan worm)	Trigger list: established	–	X	X	All	Established but restricted	X	–	Step 1 (1J)—there is likely no national interest in species management

X Species on list.

Note: Steps for assessing each species are listed in Appendix D. Impact assessment during initial screening was according to CCIMPE *Review: Update 2007–2009* (Murphy & Paini 2010) and *Species Biofouling Risk Assessment* (Hewitt et al. 2011).

Table E7 Candidate species list: *Arthropoda*

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Callinectes sapidus (Atlantic blue crab)	–	–	X	X	WA	–	X	Shane Ahyong	Step 1 (1F)—pathways and vectors cannot feasibly be managed
Caprella mutica (Japanese skeleton shrimp)	–	–	–	–	–	–	–	Richard Willan	Step 1 (1D, 1E)—species is not readily identifiable in the field and cannot feasibly be controlled in the environment
Carcinoscorpius rotundicauda (Mangrove horseshoe crab)	–	–	–	X	WA	–	–	–	Step 1 (1E)—species cannot feasibly be controlled in the environment
Carcinus maenas (European green crab)	Trigger list: established	X	X	–	NT, Qld, NSW, Tas, SA, WA	Exotic	X	–	Recommended for the APMPL

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Charybdis japonica (Asian paddle crab)	Trigger list: exotic	–	X	X	NT, Qld, NSW, SA, WA	–	X	–	Step 2 (criterion 3)—insufficient negative impacts from species
Chthamalus proteus (Atlantic barnacle)	–	–	–	X	WA	–	–	–	Step 1 (1D, 1E)—species is not readily identifiable in the field and cannot feasibly be controlled in the environment
Cirolana harfordi (Speckled pill bug)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Crangonyx floridanus (Florida crangonyctid amphipod)	–	–	–	X	–	–	–	–	Initial screening—low impact (biofouling risk assessment)
Eriocheir sinensis (Chinese mitten crab)	Trigger list: exotic	–	–	X	NT, Qld, NSW, SA, WA	Exotic	X	–	Recommended for the APMPL
Eurylana arcuata (Cirolanid isopod)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Gammarus tigrinus (Gammarid amphipod)	–	–	–	X	–	–	–	–	Initial screening—low impact (biofouling risk assessment)
Gmelinoides fasciatus (Baikalian amphipod)	–	–	–	X	–	–	–	–	Step 1 (1A, 1D, 1E)—species is freshwater only, not readily identifiable in the field, and cannot feasibly be controlled in the environment
Hemigrapsus sanguineus (Japanese/Asian shore crab)	Trigger list: exotic	–	X	X	NT, Qld, NSW, SA, WA	–	X	–	Step 1 (1D)—species is not readily identifiable in the field

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Hemigrapsus takanoi (Pacific crab)	Trigger list: exotic	–	X	–	NT, Qld, NSW, SA, WA	–	–	Shane Ahyong	Step 1 (1D)—species is not readily identifiable in the field
Hesperibalanus fallax (Warm water barnacle)	–	–	–	X	WA	–	–	–	Step 1 (1D, 1E, 1F)—species is not readily identifiable in the field, cannot feasibly be controlled in the environment, and pathways and vectors cannot feasibly be managed
Laticorophium baconi (North American Pacific corophiid)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Loxothylacus panopaei (Sacculinid parasitic barnacle)	–	–	–	X	–	–	–	–	Initial screening—parasitic species
Megabalanus rosa (Rose barnacle)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Megabalanus tintinnabulum (Acorn barnacle)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Metacarcinus novaezelandiae (Pie-crust crab)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Monocorophium acherusicum (Mediterranean corophiid)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Monocorophium insidiosum (English corophiid)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Monocorophium sextonae (Corophiid amphipod)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Pachygrapsus fakaravensi (Polynesian grapsid crab)	–	–	–	X	WA	–	–	Northern Australia Priority Pest[a]	Step 1 (1D)—species is not readily identifiable in the field
Paracerceis sculpta (Sponge-dwelling isopod)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Paradella dianae (Sphaeromatid isopod)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Petrolisthes elongatus (New Zealand half shell crab)	Watch list	–	–	–	NT, NSW	–	–	–	Step 2
Pseudodiaptomus marinus (Calaniod copepod)	–	–	X	–	WA	–	–	–	Initial screening—low impact (CCIMPE review)
Pyromaia tuberculata (American spider crab)	–	–	–	–	–	–	X	Shane Ahyong	Step 1 (1E)—species cannot feasibly be controlled in the environment
Rhithropanopeus harrisii (Harris' mud crab)	–	–	X	X	WA	–	X	Shane Ahyong, Northern Australia Priority Pest[a]	Recommended for the APMPL
Sphaeroma annandalei (Annandale's pill bug)	–	–	–	X	–	–	–	–	Step 1 (1E)—species cannot feasibly be controlled in the environment
Sphaeroma walkeri (Walker's pill bug)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Sylon hippolytes (Parasitic barnacle)	–	–	–	X	–	–	–	–	Initial screening—parasitic species
Tortanus dextrilobatu (Shrimp)	–	–	X	–	WA	–	–	–	Initial screening—low impact (CCIMPE review)

X Species on list**. a** Northern Australia Marine Pest Hazard Identification Workshop, September 2016.

Note: Steps for assessing each species are listed in Appendix D. Impact assessment during initial screening was according to CCIMPE *Review: Update 2007–2009* (Murphy & Paini 2010) and *Species Biofouling Risk Assessment* (Hewitt et al. 2011).

Table E8 Candidate species list: *Bryozoa*

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Amathia distans (Bryozoan)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Bugula flabellata (Bryozoan)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Bugula neritina (Bryozoan)	–	–	–	–	–	–	X	–	Step 1 (1E, 1F)—species cannot feasibly be controlled in the environment, and pathways and vectors cannot feasibly be managed
Cryptosula pallasiana (Bryozoan)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Schizoporella unicornis (Lace coral)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Watersipora arcuata (Lace coral)	–	–	–	–	–	–	X	–	Step 1 (1D, 1E, 1F)—species is not readily identifiable in the field, cannot feasibly be controlled in the environment, and pathways and vectors cannot feasibly be managed

X Species on list.

Note: Steps for assessing each species are listed in Appendix D. Impact assessment during initial screening was according to CCIMPE *Review: Update 2007–2009* (Murphy & Paini 2010) and *Species Biofouling Risk Assessment* (Hewitt et al. 2011).

Table E9 Candidate species list: *Cercozoa*

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Bonamia ostreae (Haplosporidian parasite, bonamia)	–	–	–	X	–	–	–	–	Initial screening—parasitic species

X Species on list.

Table E10 Candidate species list: *Chordata*

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Acanthogobius flavimanus (Yellowfin goby)	–	–	–	–	NSW, Tas, WA	–	X	–	Initial screening—low impact (CCIMPE review)
Acentrogobius pflaumi (Streaked goby)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Ascidiella aspersa (Solitary ascidian)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Botrylloides leachi (Colonial ascidian)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Botryllus schlosseri (Star ascidian)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Ciona intestinalis (Sea vase)	–	–	–	–	NT	–	X	–	Step 1 (1E, 1F)—species cannot feasibly be controlled in the environment, and pathways and vectors cannot feasibly be managed
Didemnum perlucidum (White sea squirt)	–	–	–	–	WA	–	–	Northern Australia Priority Pest List[a]	Initial screening—low impact (biofouling risk assessment)
Didemnum spp. (Colonial sea squirts—several species)	Trigger list: exotic	–	X	–	NT, Qld, NSW, SA, WA	–	X	–	Step 1 (1D)—species is not readily identifiable in the field
Didemnum vexillum (Colonial sea squirt)	–	–	–	X	WA	–	X	–	Step 1 (1D)—species is not readily identifiable in the field
Eudistoma elongatum	–	–	–	–	–	Established but restricted	–	–	Step 1 (1B)—species is native

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
(Australian native ascidian)									
Forsterygion lapillum (Common triplefin)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Forsterygion varium (Variable triplefin)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Neogobius melanostomus (Round goby)	Trigger list: exotic	–	X	–	NT, Qld, NSW, SA, WA	–	X	–	Step 1 (1A)—species is freshwater only
Siganus luridus (Dusky spinefoot)	–	–	X	–	WA	–	–	–	Initial screening—low impact (CCIMPE review)
Siganus rivulatus (Marbled spinefoot)	Trigger list: exotic	–	X	–	NT, Qld, NSW, SA, WA	–	X	–	Step 1 (1D)—species is not readily identifiable in the field
Styela clava (Clubbed tunicate)	Watch list	–	–	–	NT, NSW	Established but restricted	X	–	Step 1 (1F)—pathways and vectors cannot feasibly be managed
Styela plicata (Solitary ascidian)	–	–	–	–	–	–	X	–	Step 1 (1B, 1E, 1F)—species is native, cannot feasibly be controlled in the environment, and pathways and vectors cannot feasibly be managed

X Species on list**. a** Northern Australia Marine Pest Hazard Identification Workshop, September 2016.
Note: Steps for assessing each species are listed in Appendix D. Impact assessment during initial screening was according to CCIMPE *Review: Update 2007–2009* (Murphy & Paini 2010) and *Species Biofouling Risk Assessment* (Hewitt et al. 2011).

Table E11 Candidate species list: *Cnidaria*

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Antennella secundaria (Knotted thread hydroid)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Blackfordia virginica (Black sea jelly)	–	–	X	–	WA	–	–	–	Initial screening—low impact (CCIMPE review)
Carijoa riisei	–	–	–	–	–	–	–	John Lewis	Step 1 (1D)—species is not readily identifiable in the field
Cordylophora caspia (Hydroid)	–	–	–	–	–	–	X	–	Step 1 (1D, 1E, 1F)—species is not readily identifiable in the field, cannot feasibly be controlled in the environment, and pathways and vectors cannot feasibly be managed
Halecium delicatulum (hydroid)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Obelia dichotoma (Hydroid)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Plumularia setacea (Hydroid)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Sarsia eximia (Hydroid)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Tubastraea tagusensis (Tagusa daffodil coral)	–	–	–	–	–	–	–	John Lewis	Step 1 (1D)—species is not readily identifiable in the field

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Tubularia crocea (Pink-hearted hydroid)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)

X Species on list.

Note: Steps for assessing each species are listed in Appendix D. Impact assessment during initial screening was according to CCIMPE *Review: Update 2007–2009* (Murphy & Paini 2010) and *Species Biofouling Risk Assessment* (Hewitt et al. 2011).

Table E12 Candidate species list: *Ctenophora*

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Mnemiopsis leidyi (Comb jelly)	Trigger list: exotic	–	X	–	NT, Qld, NSW, SA, WA	–	X	–	Step 1 (1E)—species cannot feasibly be controlled in the environment

X Species on list.

Note: Steps for assessing each species are listed in Appendix D.

Table E13 Candidate species list: *Echinodermata*

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Asterias amurensis (Northern Pacific seastar)	Trigger list: established	X	X	–	NT, Qld, NSW, Tas, SA, WA	Established but restricted	X	–	Recommended for the APMPL
Astrostole scaber (Rough seastar)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Patiriella regularis (New Zealand seastar)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)

X Species on list.
Note: Steps for assessing each species are listed in Appendix D. Impact assessment during initial screening was according to CCIMPE *Review: Update 2007–2009* (Murphy & Paini 2010) and *Species Biofouling Risk Assessment* (Hewitt et al. 2011).

Table E14 Candidate species list: *Entoprocta*

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Barentsia benedeni (Nodding head)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)

X Species on list.
Note: Steps for assessing each species are listed in Appendix D. Impact assessment during initial screening was according to CCIMPE *Review: Update 2007–2009* (Murphy & Paini 2010) and *Species Biofouling Risk Assessment* (Hewitt et al. 2011).

Table E15 Candidate species list: *Mollusca*

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Anadara demiri (Ark clam)	–	–	–	X	WA	–	–	–	Initial screening—low impact (biofouling risk assessment)
Anomia nobilis (Jingle shell)	–	–	–	X	WA	–	–	Northern Australia Priority Pest List[a]	Step 1 (1D, 1E, 1F)—species is not readily identifiable in the field, cannot feasibly be controlled in the environment, and pathways and vectors cannot feasibly be managed
Anteaeolidiella indica (Japanese aeolid nudibranch)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Arcuatula senhousia (Asian bag mussel)	Trigger list: established	X	X	–	NT, Qld, NSW, SA, WA	Established but restricted	X	–	Step 1 (1D, 1E, 1F)—species is not readily identifiable in the field, cannot feasibly be controlled in the environment, and pathways and vectors cannot feasibly be managed
Brachidontes pharaonis (Variable scorched mussel)	–	–	–	X	WA	–	X	–	Step 1 (1D)—species is not readily identifiable in the field
Chiton glaucus (New Zealand chiton)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Corbicula fluminea (Asian clam)	–	–	–	X	WA	–	X	–	Step 1 (1A)—species is freshwater only
Crassostrea virginica (Eastern oyster)	–	–	–	X	WA	–	X	–	Step 1 (1D)—species is not readily identifiable in the field

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Crepidula fornicata (American slipper limpet)	Trigger list: exotic	–	X	X	NT, Qld, NSW, SA, WA	–	X	–	Step 1 (1D, 1E)—species is not readily identifiable in the field and cannot feasibly be controlled in the environment
Dreissena bugensis (Quagga mussel)	–	–	–	X	WA	–	X	–	Step 1 (1A)—species is freshwater only
Dreissena polymorpha (European zebra mussel)	–	–	–	X	WA	–	X	–	Step 1 (1A)—species is freshwater only
Ensis directus (Jack knife clam)	Trigger list: exotic	–	X	–	NT, Qld, NSW, SA, WA	–	–	–	Initial screening—low impact (CCIMPE review)
Godiva quadricolor (Aeolid nudibranch)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Geukensia demissa (Ribbed mussel)	–	–	–	X	WA	–	–	–	Step 1 (1D, 1E, 1F)—species is not readily identifiable in the field, cannot feasibly be controlled in the environment, and pathways and vectors cannot feasibly be managed
Hopkinsia plana (Dorid nudibranch)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Limnoperna fortunei (Golden mussel)	–	–	X	X	WA	–	X	–	Step 1 (1A)—species is freshwater only
Magallana ariakensis formerly *Crassostrea ariakensis* (Asian oyster)	–	–	–	X	WA	–	X	–	Step 1 (1D)—species is not readily identifiable in the field

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Magallana gigas formerly *Crassostrea gigas* (Pacific oyster)	–	X	X	–	Qld, NSW	–	X	–	Step 1 (1L—widely cultivated)
Maoricolpus roseus (New Zealand screwshell)	Trigger list: established	–	–	–	NT, Qld, NSW, SA, WA	–	X	–	Initial screening—low impact (CCIMPE review)
Mya arenaria (Soft shell clam)	Trigger list: exotic	–	X	X	NT, Qld, NSW, SA, WA	–	X	–	Step 1 (1E)—species cannot feasibly be controlled in the environment
Mytella charruana (Charru mussel)	–	–	–	X	WA	–	–	–	Step 1 (1D, 1E, 1F)—species is not readily identifiable in the field, cannot feasibly be controlled in the environment, and pathways and vectors cannot feasibly be managed
Mytilopsis leucophaeata (Dark false-mussel)	–	–	–	X	WA	–	X	–	Initial screening—low impact (CCIMPE review)
Mytilopsis sallei (Black-striped false mussel)	Trigger list: exotic	–	X	X	NT, Qld, NSW, Tas, SA, WA	–	X	–	Recommended for the APMPL
Perna canaliculus (New Zealand green-lipped mussel)	–	–	–	–	WA	–	–	–	Recommended for the APMPL
Perna perna (Brown mussel)	Trigger list: exotic	–	X	X	NT, Qld, NSW, SA, WA	–	X	–	Recommended for the APMPL
Perna viridis (Asian green mussel)	Trigger list: exotic	–	X	X	NT, Qld, NSW, SA, WA	–	X	–	Recommended for the APMPL

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Polycera capensis (Conspicuous polycera nudibranch)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Polycera hedgpethi (Hedgpeth's dorid nudibranch)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Potamocorbula amurensis (Asian clam)		–	X	X	NT, Qld, NSW, SA, WA	Exotic	X	–	Step 1 (1D, 1E)—species is not readily identifiable in the field and cannot feasibly be controlled in the environment
Raeta pulchella (Beautiful trough clam)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Rapana venosa (Rapa whelk)	Trigger list: exotic	–	X	X	NT, Qld, NSW, SA, WA	–	X	–	Step 1 (1D, 1E)—species is not readily identifiable in the field and cannot feasibly be controlled in the environment
Ruditapes largillierti (Venus clam)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)
Semimytilus algosus (Bisexual mussel)	–	–	–	–	–	–	–	John Lewis, Richard Willan	Step 1 (1D, 1E)—species is not readily identifiable in the field and cannot feasibly be controlled in the environment
Teredo navalis (Naval shipworm)	–	–	–	–	–	–	X	–	Step 1 (1D)—species is not readily identifiable in the field
Thecacera pennigera (Winged thecacera nudibranch)	–	–	–	–	–	–	X	–	Initial screening—low impact (CCIMPE review)

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Theora lubrica (Asian slippery clam)	Watch/ notification list	–	–	–	NT, NSW	–	X	–	Initial screening—low impact (CCIMPE review)
Corbula gibba (European clam)	Trigger list: established	X	X	–	NT, Qld, NSW, SA, WA	–	X	–	Initial screening—low impact (CCIMPE review)

X Species on list. **a** Northern Australia Marine Pest Hazard Identification Workshop, September 2016.

Note: Steps for assessing each species are listed in Appendix D. Impact assessment during initial screening was according to CCIMPE *Review: Update 2007–2009* (Murphy & Paini 2010) and *Species Biofouling Risk Assessment* (Hewitt et al. 2011).

Table E16 Candidate species list: *Nematoda*

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Anguillicola crassus (Parasitic nematode)	–	–	–	X	–	–	–	–	Initial screening—parasitic species

X Species on list.

Note: Steps for assessing each species are listed in Appendix D.

Table E17 Candidate species list: *Porifera*

Common name	CCIMPE list	Marine ballast water DSS	Marine pest monitoring target species list	National biofouling species of concern list	State or territory noxious list	New Zealand surveillance list	NIMPIS list	Expert recommendation	Step excluded
Cliona thoosina (Boring sponge)	–	–	–	X	WA	–	X	–	Step 1 (1D)—species is not readily identifiable in the field
Gelliodes fibrosa (Grey encrusting sponge)	–	–	–	X	WA	–	–	–	Initial screening—low impact (biofouling risk assessment)

X Species on list.

Note: Steps for assessing each species are listed in Appendix D. Impact assessment during initial screening was according to CCIMPE *Review: Update 2007–2009* (Murphy & Paini 2010) and *Species Biofouling Risk Assessment* (Hewitt et al. 2011).

Appendix F: APMPL excluded species

Table F1 Species excluded from Australian Priority Marine Pest List consideration

Phylum	Species	Common name	Reason for exclusion	Exclusion step
Algae—Chlorophyta	*Ulva australis*	Sea lettuce	Taxon under consideration is either native to Australia or cryptogenic (Womersley 1984). Its impacts would be no worse than existing native Ulva spp. (Richard Willan [APMPL task group] pers. comm.)	Step 1 (1D)—species is not readily identifiable in the field.
Algae—Miozoa	*Alexandrium catenella*	Tolxic dinoflagellate	Cannot be controlled in the environment (see Anderson 2009 for review of control and management of harmful algal blooms—HABs).	Step 1 (1E)—species cannot feasibly be controlled in the environment.
	Alexandrium minutum	Tolxic dinoflagellate	Cannot be controlled in the environment (see Anderson 2009 for review of control and management of harmful algal blooms—HABs).	Step 1 (1E)—species cannot feasibly be controlled in the environment.
	Alexandrium monilatum	Tolxic dinoflagellate	Cannot be controlled in the environment (see Anderson 2009 for review of control and management of harmful algal blooms—HABs).	Step 1 (1E)—species cannot feasibly be controlled in the environment.
	Alexandrium tamarense	Tolxic dinoflagellate	Cannot be controlled in the environment (see Anderson 2009 for review of control and management of harmful algal blooms—HABs).	Step 1 (1E)—species cannot feasibly be controlled in the environment.
	Dinophysis norvegica	Tolxic dinoflagellate	Cannot be controlled in the environment (see Anderson 2009 for review of control and management of harmful algal blooms—HABs).	Step 1 (1E)—species cannot feasibly be controlled in the environment.
	Gymnodinium catenatum	Tolxic dinoflagellate	Cannot be controlled in the environment (see Anderson 2009 for review of control and management of harmful algal blooms—HABs).	Step 1 (1E)—species cannot feasibly be controlled in the environment.
	Pfesteria piscicida	Tolxic dinoflagellate	Cannot be controlled in the environment (see Anderson 2009 for review of control and management of harmful algal blooms—HABs).	Step 1 (1E)—species cannot feasibly be controlled in the environment.
Algae—Ochrophyta	*Chaetoceros concavicornis*	Centric diatom	Cannot be controlled in the environment (see Anderson 2009 for review of control and management of harmful algal blooms—HABs).	Step 1 (1E)—species cannot feasibly be controlled in the environment.

Phylum	Species	Common name	Reason for exclusion	Exclusion step
	Chaetoceros convolutus	Centric diatom	Cannot be controlled in the environment (see Anderson 2009 for review of control and management of harmful algal blooms—HABs).	Step 1 (1E)—species cannot feasibly be controlled in the environment.
	Chatonella antiqua	Raphidophyte	Cannot be controlled in the environment (Richard Willan [APMPL task group] pers. comm.)	Step 1 (1E)—species cannot feasibly be controlled in the environment.
	Corethron criophilum	Diatom	Cannot be controlled in the environment (Richard Willan [APMPL task group] pers. comm.)	Step 1 (1E)—species cannot feasibly be controlled in the environment.
	Pseudochattonella farcimen	Raphidophyte	It is an ichthyotoxic, microscopic (less than 20 microns), planktonic heterokont flagellate (Dictyochophyceae), therefore is not readily identified and cannot be controlled in the environment (John Lewis [APMPL task group] pers. comm.)	Step 1 (1D, 1E)—species is not readily identifiable in the field and cannot feasibly be controlled in the environment.
	Pseudo-nitzschia seriata	Pennate diatom	Cannot be controlled in the environment (Richard Willan [APMPL task group] pers. comm.)	Step 1 (1E)—species cannot feasibly be controlled in the environment.
Annelida	*Hydroides elegans*	Fouling serpulid polychaete worm	Not readily identifiable at species level in the field, but is identifiable in the laboratory (Tim Glasby, John Lewis [APMPL task group] pers. comm.). It is recorded from all Australian States and the Australian Capital Territory and Northern Territory. It is cryptogenic, possibly native (Sun et al. 2015).	Step 1 (1D)—species is not readily identifiable in the field.
	Marenzelleria spp.	Red-gilled mudworm	Part of a complex of 6 species. Not readily identifiable at species level (Chris Glasby [APMPL technical expert] pers. comm.).	Step 1 (1D—not readily identifiable in the field/species complex).
	Polydora ciliata	Spionid polychaete worm	Unresolved complex of five putative subspecies according to WoRMS (Bellan 2017; Manchenko & Radashevsky 1998). Arrival in Australia could negatively impact aquaculture (Lexie Walker [APMPL technical expert] pers. comm.).	Step 1 (1D—not readily identifiable in the field/species complex).
	Polydora cornuta	Spionid polychaete worm	These polydorid mudworms cannot be identified in the field; they require a microscope and expertise. There are few control options; they live on all live and dead hard substrates including to depths of greater than 50 m, and are chemically resistant because they can retract into their tube (Marty Deveneyr [APMPL task group] pers. comm.).	Step 1 (1D—not readily identifiable; 1E—cannot feasibly be controlled in the environment).
	Polydora nuchalis	Spionid polychaete worm	Unresolved complex of species. Cryptogenic. Not readily identifiable. Extremely difficult to control in the natural environment and very difficult	Step 1 (1D—not readily identifiable in the field/species complex).

Phylum	Species	Common name	Reason for exclusion	Exclusion step
			to manage spread (Chris Glasby & Lexie Walker [APMPL technical expert] pers. comm.).	
	Polydora websteri	Spionid polychaete worm	These polydorid mudworms are impossible to ID in the field—they require a microscope and considerable expertise. There are few control options—they live on all live and dead hard substrates including to depths of greater than 50 m, and are chemically resistant because they can retract into their tube (Marty Deveneyr [APMPL task group] pers. comm.).	Step 1 (1D, 1E)—species is not readily identifiable in the field and cannot feasibly be controlled in the environment.
Arthropoda	*Briarosaccus callosus*	Parasitic barnacle	Australian native species (Shane Ahyong [APMPL technical expert] pers. comm.). Parasitic species (Boschma 1930).	Step 1 (1B—species is native). Parasitic species excluded from process
	Loxothylacus panopaei	Sacculinid parasitic barnacle	Parasitic species (Ingo Ernst [APMPL task group] pers. comm.; Fofonoff et al. 2017). Impacts localised to aquaculture (Richard Willan [APMPL task group] pers. comm.)	Parasitic species excluded from process.
	Sphaeroma annandalei	Isopod	The argument is that this isopod is cryptogenic/unmanageable because of its (wood-boring) habitat. Eradication would be impossible. Spread similarly impossible to manage (Cragg et al. 1999).	Step 1 (1E)—species cannot feasibly be controlled in the environment.
	Sylon hippolytes	Parasitic barnacle	Parasitic species (Ingo Ernst [APMPL task group] pers. comm.; Lutzen 1981). Impacts localised to aquaculture.	Parasitic species excluded from process.
Bryozoa	*Bugula neritina*	Bryozoan	The species is in all potential distributions; vectors could not feasibly be managed to prevent its spread; no previous attempts have been made to control the species in Australia, and as such, there would be no national interest in containing its spread and improving its management.	Step 1 (1E—cannot feasibly be controlled in the environment; 1F—pathways and vectors cannot feasibly be managed; 1J—lack of national interest in management; 1M—already established in all potential jurisdictions).
Chordata	*Ciona intestinalis*	Sea vase	The species is established in all potential distributions where it could occur; vectors could not feasibly be managed to prevent its spread; no previous attempts have been made to control the species in Australia, and as such, there would be no national interest in containing its spread and improving its management.	Step 1 (1E—cannot feasibly be controlled in the environment; 1F—pathways and vectors cannot feasibly be managed; 1J—lack of national interest in management; 1M—already established in all potential jurisdictions).
	Didemnum spp.	Colonial sea squirts (several species)	Part of a massive (and not resolved) species complex. Not readily identifiable at species level (Kott 2004; Stefaniak et al. 2012).	Step 1 (1D—not readily identifiable in the field/species complex).

Phylum	Species	Common name	Reason for exclusion	Exclusion step
	Eudistoma elongatum	Australian native ascidian	Native to Australia (Kott 1990).	Step 1 (1B—species is native).
Ctenophora	*Mnemiopsis leidyi*	Comb jelly	Not able to be controlled in the natural environment (Galil 2002).	Step 1 (1E)—species cannot feasibly be controlled in the environment.
Mollusca	*Brachidontes pharaonis*	Variable scorched mussel	Part of a massive (and far from resolved) species complex involving native spp. like *B. maritimus* and *B. ustulatus* (Rosenberg & Gofas 2012). Not readily identifiable at species level.	Step 1 (1D—not readily identifiable in the field/species complex).
	Corbicula fluminea	Asian clam	Freshwater species (Aldridge et al. 2012; GISD 2017b).	Step 1 (1A)—species is freshwater only.
	Crassostrea ariakensis	Suminoe oyster, Asian oyster	Not readily identifiable (Reece et al. 2008). Nuisance biofouling species only.	Step 1 (1D—not readily identifiable in the field/species complex).
	Crassostrea virginica	Eastern oyster	Not readily identifiable (Reece et al. 2008).	Step 1 (1D—not readily identifiable in the field/species complex).
	Dreissena bugensis	Quagga mussel	Wholly freshwater species (Rintelen & Van Damme 2011; GISD 2017c)	Step 1 (1A)—species is freshwater only.
	Dreissena polymorpha	European zebra mussel	Freshwater species, can tolerate brackish waters and low salinity waters (GISD 2017d). However, impacts predominately in freshwater (CABI 2017d).	Step 1 (1A)—species is freshwater only.
	Limnoperna fortunei	Golden mussel	Freshwater species (CABI 2017g; GISD 2017f).	Step 1 (1A)—species is freshwater only.
	Magallana gigas (formerly Crassostrea gigas)	Pacific oyster	Widely cultivated in Australia (Maguire & Nell 2007).	Step 1 (1L—widely cultivated).
	Teredo navalis	Naval shipworm	Not readily identifiable, similar species exist in Australia (NIMPIS 2017t). It is possibly native.	Step 1 (1D—not readily identifiable in the field/species complex).
Nematoda	*Anguillicola crassus*	Parasitic nematode	Not likely to be controllable. Impact localised to aquaculture. (Richard Willan [APMPL task group] pers. comm.). Parasitic species of eels in Japan and Europe; may also infect freshwater fish (Haenen & van Banning 1990).	Parasitic species excluded from assessment.
Porifera	*Cliona thoosina*	Boring sponge	Nuisance biofouling. Part of a complex of species (van Soest 2008), not readily identifiable at species level.	Step 1 (1D—not readily identifiable in the field/species complex).

Appendix G: APMPL marine pest species assessments

Algae

Codium fragile spp. *fragile*

Phylum: Algae—Chlorophyta

Common name: Dead man's fingers

Status: Established

Assessed by John Lewis; reviewed by Jessica Evans

Table G1 Step 1 assessment for *Codium fragile* spp. *fragile*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Codium fragile* spp. *fragile* is listed as inhabiting marine environments on the AlgaeBase database (Guiry 2017a). Adult salinity tolerance ranges vary between 12–40 ppt (Bridgwood 2010; NIMPIS 2017e) and 17.5–40 ppt (O'Loughlin et al. 2006). Adult temperature range is –2 °C to 34 °C, but reproductive temperature is 10 °C to 24 °C (O'Loughlin et al. 2006; Bridgwood 2010).
1B	The species is not native.	True	The earliest Australian record of *C. fragile* spp. *fragile* is from 1985 in Tasmania (Provan et al. 2008).
1C	The species is not on the EPBC Act live import list.	True	*C. fragile* spp. *fragile* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	The invasive subspecies can often, but not always, be differentiated from native subspecies on morphological form (shrubbier habit) and habitat in sheltered waters, particularly in shallow subtidal on shelly or gravelly sand or on artificial structures (John Lewis [APMPL task group] pers. comm.). There are also congeneric species is Australian waters with similar morphology—microscopic identification is usually required for a reliable identification (Trowbridge 1999).
1E	The species could feasibly be controlled in the environment.	False	*C. fragile* spp. *fragile* exhibits apomictic life history, vegetative propagation, tendency to detach and drift, and persistent basal attachments, making control close to impossible (Trowbridge 1990; Watanabe et al. 2009). There are very few control options for this species as vegetative propagation is possible, most mechanical methods and manual removal are not an option because fragments often break off whilst being removed, leading to further spread of the algae (Bridgwood 2010). Chemical control is unlikely due to the impact on

Criterion code	Criterion	True or false	Justification
			other species. The species has not been actively managed or responded to in the last 40 years for the incursions in New Zealand and the Atlantic (Bridgwood 2010).
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	*C. fragile* spp. *fragile* exhibits opportunistic and invasive traits which—together with desiccation tolerance that allows translocation on vessel decks or entangled in fishing gear (Schaffelke & Deane 2005)—have facilitated spread to all temperate jurisdictions.
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	False	Because control options are not viable and *C. fragile* spp. *fragile* has already spread to all temperate jurisdictions, there may not be a national interest to further contain its spread.
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	*C. fragile* spp. *fragile* has established in New South Wales, Victoria, Tasmania, and South Australia and there is a known incursion in Western Australia (NIMPIS 2017e).
1L	The species is not widely cultivated in Australia.	True	*C. fragile* spp. *fragile* is not widely cultivated.
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	False	*C. fragile* spp. *fragile* has established in New South Wales, Victoria, Tasmania, and South Australia and there is a known incursion in Western Australia, which is likely the potential range of the species.
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	Disjunct distributions are most likely attributable to fishing gear, fishing vessels or small vessels or other moveable structures with heavy fouling.
2	This species progresses to Step 2 (all criteria are true).	False	*C. fragile* spp. *fragile* does not pass Step 1: it is difficult to accurately identify in the field (1D); it cannot feasibly be controlled in the environment (1E); pathways and vectors could not feasibly be managed (1F); it is established in all jurisdictions where it is likely to occur (1K); and there is unlikely to be national interest in containing its spread and improving its management (1J).

Gracilaria vermiculophylla

Phylum: Algae—Rhodophyta

No common name

Status: Exotic

Assessed by John Lewis; reviewed by Jessica Evans

Table G2 Step 1 assessment for *Gracilaria vermiculophylla*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Gracilaria vermiculophylla* is listed as inhabiting marine environments on the AlgaeBase database (Guiry 2017b). The species has a wide range of salinity tolerances (5–60 ppt) and temperatures (5–35 °C). Growth experiments conducted by Rueness (2005) suggested that the optimal temperature was 19.5 °C and salinity of 10 ppt for best growth, but also achieved good growth at 11 °C to 25 °C and salinity of 20 ppt to 30 ppt (Rueness 2005). The optimal temperature for growth has also been reported as being between 15 °C and 25 °C and salinity of 10 ppt to 45 ppt (Rainkar et al. 2001; Rueness 2005 as cited in GISD 2017e).
1B	The species is not native.	True	The global distribution of *G. vermiculophylla* is listed on AlgaeBase, which does not include listing any distribution in Australia (Guiry 2017b). It is native to north-east Asia (Korea, China and Japan) and Russia, and has been introduced in Europe (Germany, Sweden, France, Denmark, Morocco, Netherlands, Portugal and Spain) and North America (Baja, California to British Columbia and Virginia to Rhode Island) (Rueness 2005; Kim et al. 2010). There is the potential for undetected presence of the species in Australia, due to its similarity to congeners (John Lewis [APMPL task group] pers. comm.).
1C	The species is not on the EPBC Act live import list.	True	*G. vermiculophylla* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	There are more than 170 species of *Gracilaria* and *Gracilariopsis,* and the morphological similarity of this and related species makes invasions cryptic and DNA analysis is required for reliable identification (Thomsen et al. 2006a, 2006b; Saunders 2009). *Gracilaria* spp. in Australia are notoriously difficult to separate morphologically, and we have species that do cause blooms similar to that of *G. vermiculophylla* in the invaded range. Detection is only likely after a bloom appears and DNA analysis is completed. Therefore, this species could not easily be detected with a great deal of taxonomic certainty or distinguished from natives without the use of molecular methods.
1E	The species could feasibly be controlled in the environment.	False	Control of *G. vermiculophylla* is difficult due to its vegetative propagation and formation of free-floating blooms in shallow water bays and estuaries. The species has parallels with *Codium*, which has been unable to be contained. A potential control method if the species is detected in a small area is mechanical—as is often used

Criterion code	Criterion	True or false	Justification
			for harvesting of agar (GISD 2017e). However, this may not be effective if spores are released and are not continuously mechanically removed.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	Vector management of *G. vermiculophylla* is difficult. Spread would most likely be by transportation of fragments—similar to *Caulerpa* and *Codium*, but viable from smaller fragments. Entanglement in vessel or fishing gear, or entrainment in water systems are the most probable vectors.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	There is a possibility that *G. vermiculophylla* is, or has been present in Australia, but not identified because of its similarity to congeners (John Lewis [APMPL task group] pers. comm.).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	Overseas introductions have been associated with aquaculture and the movement of oysters (ISSG 2016). *G. vermiculophylla* can survive months in darkness so there is potential for transportation in ballast or under dehydration (up to 19%) (Nyberg & Wallentius 2009). May be translocated by small fragments in fishing nets, ballast tanks, diving equipment or by migrating seabirds (Nyberg & Wallentius 2009).
1I	The species has the potential to become established in Australian waters	True	*G. vermiculophylla* can survive in a broad range of conditions—both tropical and temperate waters. It can tolerate a wide range of temperatures (5–35 °C), light intensities (20–100 µmol photons m^2/s) and salinities (5–60 ppt). Growth experiments conducted by Rueness (2005) suggested that optimal temperature was 19.5 °C and salinity of 10 ppt for best growth, but also achieved good growth at 11 °C to 25 °C, and salinity of 20 ppt to 30 ppt (Rueness 2005). The optimal temperature for growth has also been reported between 15 °C and25 °C and salinity of 10 ppt and 45 ppt (Rainkar et al. 2001; Rueness 2005 as cited in GISD 2017e). It is also tolerant to other stresses including sedimentation, desiccation, grazing, low nutrients and low light (Nyberg et al. 2009; Thomsen & McGlathery 2007).
2	This species progresses to Step 2 (all criteria are true).	False	*G. vermiculophylla* does not pass Step 1: it would be difficult to accurately identify in the field (1D); it could not feasibly be controlled in the environment (1E); and pathways and vectors could not feasibly be managed (1F).

Grateloupia imbricata

Phylum: Algae—Rhodophyta

No common name

Status: Established

Assessed by John Lewis; reviewed by Jessica Evans

Table G3 Step 1 assessment for *Grateloupia imbricata*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Grateloupia imbricata* is listed as a marine species on AlgaeBase (Guiry 2015).
1B	The species is not native.	True	The species is not native to Australia. It is listed as introduced to Western Australia, though no date of introduction can be found (Huisman et al. 2008). *Grateloupia imbricata* is an Asian species, native to Japan and Korea (Garcia-Jimenez et al. 2008). It has been introduced to the Canary Islands (Garcia-Jimenez et al. 2008) and Spain (Montes et al. 2016).
1C	The species is not on the EPBC Act live import list.	True	*G. imbricata* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	The *G. imbricata* morphology is quite distinctive among other algae in shallow subtidal habitats in Australian inshore waters. Although Montes et al. (2016) cites that 'The genus *Grateloupia* is the largest of the family Halymeniaceae. The complex taxonomy of the genus, together with recent studies using molecular data, has resulted in what has been called a state of 'taxonomic flux' (Gargiulo et al. 2013 and references therein, as cited in Montes et al. 2016)'. There are no native *Grateloupia* species across southern Australia and the introduced species *G. pectinata* and *G. turuturu* are morphologically distinct. Anyone with a reasonable knowledge of the native macroalgal flora would be expected notice this species (John Lewis [APMPL task group] pers. comm.).
1E	The species could feasibly be controlled in the environment.	True	Like that in Australia, overseas introductions of *G. imbricata* are typically small populations. Therefore, could feasibly be managed.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	Aquaculture and biofouling management could feasibly prevent the spread of *G. imbricata*.
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	False	Non-indigenous *G. imbricata* populations overseas have not (yet) been highly invasive nor formed extensive populations. Therefore, it is unlikely that there is a national interest in containing the species spread and improving its management at this stage (John Lewis, pers. comm.).

Criterion code	Criterion	True or false	Justification
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	False	In Australia, *G. imbricata* is established as a single population at Cottesloe, Western Australia. It is unknown if delimitation surveys have been undertaken (Huisman et al. 2008). This population may be feasible to remove.
1L	The species is not widely cultivated in Australia.	True	*G. imbricata* is not cultivated in Australia. Only one population has established in Cottesloe, Western Australia.
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	True	*G. imbricata* is only known from one population, in Cottesloe in Western Australia.
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	*G. imbricata* is most likely to have been transported to the Canary Islands., Spain and Australia on vessels. The species could spread via aquaculture and shipping (ballast or hull fouling) as these are thought to be the method of introduction (Garcia-Jimenez 2008; Montes et al. 2016).
2	This species progresses to Step 2 (all criteria are true).	False	*G. imbricata* does not pass Step 1: there is not likely to be a national interest in containing the species' spread and improving its management (1J); it is unknown if the single population established in Cottesloe, Western Australia can be feasibly removed (1K).

Grateloupia turuturu

Phylum: Algae—Rhodophyta

Common name: Devil's tongue weed

Status: Established

Assessed by John Lewis; reviewed by Jessica Evans

Table G4 Step 1 assessment for *Grateloupia turuturu*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Grateloupia turuturu* is a marine species (Guiry 2017g).
1B	The species is not native.	True	The first confirmed record of *G. turuturu* in Australia is 2004 (Saunders & Withall 2006) and was not found in extensive collections of foliose red algae prior to 1994 (Womersley & Lewis 1994). It is widely spread along the Portuguese coast and has been reported on the Atlantic coasts of Europe, New Zealand and North America and in the Mediterranean Sea (Cabioch et al. 1997; Villalard-Bohnsack & Harlin 1997; Ba´rbara & Cremades 2004;

Criterion code	Criterion	True or false	Justification
			D'Archino et al. 2007; as cited in Araujo et al. 2011). *Grateloupia turuturu* is native to Japan (Araujo et al. 2011 and references within).
1C	The species is not on the EPBC Act live import list.	True	*G. turuturu* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	*G. turuturu* is very difficult to distinguish from the native *Rhodoglossum gigartinoides* in the field, and confusion has occurred in both Tasmania and Port Phillip Bay (John Lewis [APMPL task group] pers. comm.). It can also be confused with *Schizymenia* species (native/alien/cryptogenic) (John Lewis [APMPL task group] pers. comm.). It would also be difficult to distinguish it from the foliose *Gigartina* spp. with confidence; or with *Porphyra* spp. (Richard Willan, pers. comm.). Definite identification is only possible by sectioning and microscopy or molecular methods.
1E	The species could feasibly be controlled in the environment.	False	*G. turuturu* is highly and continuously fertile from a young age, and can perennate from the basal attachment disc (John Lewis 2011). Subsequent to the initial detection in Bicheno, Tasmania (Saunders & Withall 2006), follow up surveys found it had already established from St Helens to Coles Bay and in the D'Entrecasteaux Channel south of Hobart (John Lewis [APMPL task group] pers. comm.). Spread in Port Phillip Bay has also been unpredictable, with the first confirmed record at Point Cook (2010), with subsequent collections in Portland (2010) and Hobsons Bay (2011) (John Lewis [APMPL task group] pers. comm.). No effective control measures have happened overseas.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	The introduction of *G. turuturu* to Tasmania seems linked to oyster importation (Saunders & Withall 2006). Although it can colonise vessel hulls, regional spread appears to be by natural dispersal by drifting of fertile blades and by stone-rafting (as cited in Araujo et al. 2011).
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	False	No significant impacts have been attributed to introduced populations in the wild; therefore, it is unlikely that there is a national interest in containing the spread of this species. The findings of an experimental study by Mulas and Bertocci (2016) suggested that *G. turuturu* relies on disturbances removing potential native competitors rather than being the main driver of ecological alterations. However, observations in Australia suggest that it can colonise and coexist in native communities without causing displacement or disruption of native algal communities (John Lewis [APMPL task group] pers. comm.).
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	*G. turuturu* is well established in Port Phillip Bay (Christie & Awal 2016; John Lewis [APMPL task group] pers. comm.) and on Tasmanian coasts (Saunders & Withall 2006; John Lewis [APMPL task group] pers. comm.).
1L	The species is not widely cultivated in Australia.	True	*G. turuturu* has been proposed as food for farmed abalone, but is not yet farmed for this purpose.

Criterion code	Criterion	True or false	Justification
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	True	*G. turuturu* has only been confirmed from Tasmania (Saunders & Withall 2006; John Lewis [APMPL task group] pers. comm.), Victoria (Christie & Awal 2016; John Lewis [APMPL task group] pers. comm.) and New Zealand (D'Archino et al. 2007).
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	Introduction of *G. turuturu* is most likely associated with aquaculture, but feasibly via heavily fouled vessels and ballast (Araujo et al. 2011 and references within). Spread to new jurisdictions would be most likely linked to vessel or immersed infrastructure movements in fouling and, less likely, in ballast. The lack of known spread to date suggests low transport incidence, but spread could be cryptic due to lack of surveys and identification skills in potential observers.
2	This species progresses to Step 2 (all criteria are true).	False	*G. turuturu* does not pass Step 1: it is difficult to accurately identify in the field (1D); it cannot feasibly be controlled in the environment (1E); pathways and vectors cannot feasibly be managed (1F); and there is unlikely to be national interest in containing the species' spread and improving its management (1J).

Sargassum horneri

Phylum: Algae—Ochrophyta

Common name: Horner's seaweed

Status: Exotic

Assessed by John Lewis; reviewed by Jessica Evans

Table G5 Step 1 assessment for *Sargassum horneri*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Sargassum horneri* is listed as inhabiting marine environments on the AlgaeBase database (Guiry 2017c)
1B	The species is not native.	True	*S. horneri* is exotic to Australia; its native distribution is Korea and Japan (Marks et al. 2015).
1C	The species is not on the EPBC Act live import list.	True	*S. horneri* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty	False	*S. horneri* has a distinctive morphology with flattened branches with alternately arranged flattened and truncate laterals toothed on the outer margin. However, the separation of juvenile and perennial plant parts would be difficult to distinguish from native *Sargassum* and plants with fertile side branches could be confused with native Fucaleans such as *Myriodesma* and some *Cystophora* species. There are around 350 *Sargassum* species worldwide (AlgaeBase) with 15 listed in southern Australia (Womersley 1987), 26 from New South Wales (Millar

Criterion code	Criterion	True or false	Justification
	• distinguishable from natives in the field.		& Krafft 1994). Australian species of *Caulocystis*, *Acrocarpia*, *Myriodesma* and *Cystophora* also exhibit morphological similarity. More species are likely cryptic or undescribed. Identification in the field would be difficult, and almost impossible for juveniles associated with other rock weeds. *S. horneri* has previously been confused with another exotic, *Sargassum filicinum*, when a population was identified in California. However, the species can be separated by differences in gametes (*S. filicinum* is monecious, *S. horneri* is dioecious) and *S. filicinum* has ellipsoidal pneumatocysts whereas *S. horneri* has spherical pneumatocysts Engle, J, Miller, KA & Alstatt, J n.d.). However, *S. filicinum* is not a native and not present in Australia, so is unlikely a concern for identification.
1E	The species could feasibly be controlled in the environment.	False	If the colonising population is detected in the year of establishment, there is a chance of controlling *S. horneri*, but detection at this stage is highly improbable. However, attempts to eradicate the congener *S. muticum* have never been successful. *S. horneri* would not be recognisable until the fertile side branches are present, so after spore release. A study by Marks et al. (2017) is a demonstration of the inability to eradicate this species.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	*S. horneri* vectors and pathways could feasibly be managed by removal of reproductive branches before spore maturation and annual shedding.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*S. horneri* is exotic to Australia; its native distribution is Korea and Japan (Marks et al. 2015).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	Uncertain, as the single overseas introduction of *S. horneri*, to California could be inferred to be via ballast water, which is managed on vessels arriving in Australia.
1I	The species has the potential to become established in Australian waters	True0	A study of growth and maturation of *S. horneri* in Hiroshima bay suggested that temperatures ranges from 10 °C to 28 °C in Ohno-seto strait and 10 °C to 26 °C in Matsugahana over the course of a 2 year study (Yoshido et al. 2001). Therefore, given temperature only, it is likely the algae could establish in Australia.
2	This species progresses to Step 2 (all criteria are true).	False	*S. horneri* does not pass Step 1: it would be difficult to accurately identify in the field (1D); and it could not feasibly be controlled in the environment (1E).

Sargassum muticum

Phylum: Algae—Ochrophyta

Common name: Asian seaweed

Status: Exotic

Assessed by John Lewis; reviewed by Jessica Evans

Table G6 Step 1 assessment for *Sargassum muticum*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Sargassum muticum* is listed as inhabiting marine environments on the AlgaeBase database (Guiry 2017d). Optimal salinity for growth is 34 ppt, but it can survive at 5 ppt to 6 ppt, although reproduction does not usually occur under 16 ppt. The species requires a temperature of at least 8 °C for over 4 months to enable reproduction (Josefsson & Jansson 2011).
1B	The species is not native.	True	*S. muticum* is not present in Australia (NIMPIS 2017q). The species is native to the north-western Pacific, and is found in the coastal waters of Japan, China, Russia, and Korea. It is introduced to Canada, North America (Alaska to California and Mexico) and Europe (England, Portugal, Norway, Italy, Denmark and Germany) (Joseffson & Jansson 2011 and references within).
1C	The species is not on the EPBC Act live import list.	True	*S. muticum* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	There are around 350 *Sargassum* species worldwide (AlgaeBase), with 15 listed in southern Australia (Womersley 1987), 26 from New South Wales (Millar & Krafft 1994). Australian species of *Caulocystis*, *Acrocarpia*, *Myriodesma* and *Cystophora* also exhibit morphological similarity. More species are likely cryptic or undescribed. Identification in the field would be difficult, and almost impossible for juveniles associated with other rock weeds.
1E	The species could feasibly be controlled in the environment.	False	*S. muticum* has not been controlled overseas, and has spread widely with no apparent restraint. Manual removal is an option. Although this species does not reproduce vegetatively, embryos detach from the branches and can spread via drifting fertile branches; therefore, care needs to be taken to ensure branches do not fall off with manual removal. However, manual removal has not proven to be very successful in the control of this species (Josefsson & Jansson 2011).
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	Primary overseas introductions of *S. muticum* have been attributable to oyster transport (Farnham & Jones 1974; Lewis 2011). The species can occur on heavily fouled structures and vessels (Abbott & Huisman 2004), but improbable on regular vessel hulls due to reproduction by release of germlings (John Lewis [APMPL task group]

Criterion code	Criterion	True or false	Justification
			pers. comm.). Entanglement in vessels and fishing gear is a likely contributor to regional spread (Critchley et al. 1983).
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*S. muticum* is not present in Australia (NIMPIS 2017q).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	Although feasible, it is considered unlikely due to controls on oyster imports, ballast water management, and being a small biofouling risk.
1I	The species has the potential to become established in Australian waters	True	Optimal salinity for *S. muticum* growth is 34 ppt, but it can survive of 5 ppt to 6 ppt, although reproduction does not usually occur under 16 ppt. The species requires a temperature of at least 8 °C for over 4 months to enable reproduction (Josefsson & Jansson 2011).
2	This species progresses to Step 2 (all criteria are true).	False	*S. muticum* does not pass Step 1: it would be difficult to accurately identify in the field (1D); and it could not feasibly be controlled in the environment (1E).

Schizymenia apoda

Phylum: Algae—Rhodophyta

No common name

Status: Established

Assessed by John Lewis; reviewed by Jessica Evans

Table G7 Step 1 assessment for *Schizymenia apoda*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Schizymenia apoda* is listed as a marine species on the AlgaeBase database (Guiry 2017e)
1B	The species is not native.	True	*S. apoda* is introduced, not native to Australia, with the earliest Australian record collected from Port MacDonnell, South Australia in 1991 (Saunders et al. 2015). Subsequent confirmed collections of the species are from Warrnambool, Victoria in 2004 and 2011 (Saunders et al. 2015). Earlier introduction of the species is possible, such as in Portland, Victoria, and Ulladulla, Jervis Bay and Manly, New South Wales (Saunders et al. 2015), where *S. apoda* is genetically introgressed with the cryptogenic *S. dubyi*. As such, the full history of the species in Australia is uncertain. To quote Gary Saunders (University of New Brunswick, Canada), '*Schizymenia* is

Criterion code	Criterion	True or false	Justification
			a huge mess… We have collected two species from Australia now, including samples from Sydney to Warrnambool. They may be hybridizing and nobody knows what true *apoda* actually is … A nightmare is the only conclusion…'. Its type locality is Table Bay (South Africa) (Silva 1980 as cited in D'Archino & Zuccarello 2013), and along the entire South African west coast (Stegenga et al. 1997 as cited in D'Archino & Zuccarello 2013). It is also found in Namibia, Somalia and St Paul Island (Indian Ocean) (Guiry & Guiry 2013 as cited in D'Archino and Zuccarello 2013), and in New Zealand (D'Archino & Zuccarello 2013).
1C	The species is not on the EPBC Act live import list.	True	*S. apoda* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	The genus has a distinctive morphology relative to other native algal species in the upper sublittoral zone where it has been found in harbour precincts in Australia and New Zealand. It can be confused with the exotic *Grateloupia turuturu*, and the species went unnoticed for 5 years in Wellington, New Zealand due to this similarity (D'Archino & Zuccarello 2014). The two species can be easily separated microscopically, primarily by the presence of gland cells in the cortex of the former. Separation from the cryptogenic and most probably introduced *S. dubyi* can only be done with certainty by molecular methods (Saunders et al. 2015). Plants morphologically indistinguishable from *S. apoda* collected at Williamstown have been genetically determined to be pure *S. dubyi* (Saunders et al. 2015), a cryptogenic but most probably introduced species.
1E	The species could feasibly be controlled in the environment.	False	*S. apoda* has a heteromorphic alternation of generations with a crustose sporophyte. Populations would therefore be difficult to eradicate once established (John Lewis [APMPL task group] pers. comm.).
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	The vector for the introduction of *S. apoda* is unknown, and the time of introduction is unknown due to the unresolved taxonomy of species within the genus in Australia (Saunders et al. 2015). Though the most likely vectors are biofouling or aquaculture, the lack of certainty in identity and distribution makes a definitive answer difficult. Good vessel and aquaculture hygiene may limit spread, but no outcome can be asserted because of uncertainty.
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	False	No harmful effects or invasive traits have been observed from known introductions of *S. apoda*; therefore, it is unlikely that there would be a national interest in containing the species spread and improving its management.
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	*S. apoda* has a heteromorphic alternation of generations with a crustose sporophyte. Populations would therefore before difficult to eradicate once established (John Lewis [APMPL task group] pers. comm.).
1L	The species is not widely cultivated in Australia.	True	*S. apoda* is not cultivated.

Criterion code	Criterion	True or false	Justification
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	True	*S. apoda* is only known with certainty from Victoria (Warrnambool and Williamstown) and South Australia (Port MacDonell) (Saunders et al. 2015; John Lewis [APMPL task group] pers. comm.).
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	Uncertain, given that the vectors for spread can only be inferred, and the Australian distribution is unresolved.
2	This species progresses to Step 2 (all criteria are true).	False	*S. apoda* does not pass Step 1: it is difficult to accurately identify in the field (1D); it cannot feasibly be controlled in the environment (1E); pathways and vectors cannot feasibly be managed (1F); and there is unlikely to be national interest in containing the species' spread and improving its management (1J).

Undaria pinnatifida

Phylum: Algae—Ochrophyta

Common names: Japanese seaweed, wakame

Status: Established

Assessed by John Lewis; reviewed by Jessica Evans

Table G8 Step 1 assessment for *Undaria pinnatifida*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Undaria pinnatifida* is listed as inhabiting marine environments on AlgaeBase (Guiry 2017f). The salinity range of the species has been documented as 18.5 ppt to 40 ppt (NIMPIS 2017u), with optimal salinity for growth between 27 ppt and 33 ppt (Bardach et al. 1972 as cited in O'Loughlin et al. 2006). However, the species has been recorded at 22 ppt and 23 ppt in New Zealand (Wallentinus 1999 as cited in O'Loughlin et al. 2006).
1B	The species is not native.	True	*U. pinnatifida* is not native or naturalised to Australia; it has spread to other countries from Asia in the 1970s (CABI 2017j).
1C	The species is not on the EPBC Act live import list.	True	*U. pinnatifida* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty	True	*U. pinnatifida* has similarities to *Ecklonia radiata*, a native algae. However, sporophytes of *Undaria* can be separated from *Ecklonia* by the sporophyll, which has a mass of tissue attached to the lower half of the stem, which has a convoluted appearance (DPIPWE 2015), as well as a central midrib along the lamina (Australian Emergency Marine Pest Plan 2015). It can also be identified using DNA barcoding (Bott & Giblot-Ducray 2011).

Criterion code	Criterion	True or false	Justification
	• distinguishable from natives in the field.		The species would be hard to identify at the microscopic haploid stage without molecular tools. This stage can also be dormant for long periods.
1E	The species could feasibly be controlled in the environment.	True	Only if colonisations are detected early and the population can be confined. The National control plan for *U. pinnatifida* suggests that small-scale populations (less than 1,000 m^2) could be controlled by physically removing the plants—which is really the only effective method for control. It is probably not feasible to control large populations (Aquenal 2008c). Small-scale (less than 800 m^2) removal of a population in Tasmania was effective. However, hotspots came up from time to time. Microscopic stages do create a seedbank. However, Hewitt et al. (2005) (as cited in Aquenal 2008c) suggested that manual removal needs to be long term combined with vector management and education to reduce re-inoculation and a large scale spatial monitoring to allow rapid detection of new incursions. The one known instance of an apparently successful eradication was following the discovery of 8 immature plants growing on abalone shells in Western Port, Victoria (Parry & Cohen 2001b). There are no examples of eradication elsewhere, and control would likely only be possible (as in Western Port) if the population was 100 m^2 at most and only if also limited in reproduction and spread by environmental conditions.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	Regional spread of *U. pinnatifida* is associated with aquaculture and small vessel movements. Unmanaged ballast water can potentially translocate detached sporophylls. The degree of management would depend on the size of the intervention. For example, regular maintenance of small vessel hulls and antifouling systems of all small craft in infected regions, which represent the high-risk vector. According to the National control plan, *U. pinnatifida* attaches to floating structures and can be transferred via biofouling. The main vector for both inter-regional and intra-regional spread to new locations has been via fouling of vessel hulls (Hay 1990) and aquaculture. These vectors are feasible to manage and translocation risk could be reduced if national best practice management guidelines for management of biofouling and aquaculture are comprehensively followed, and particularly for little used and derelict vessels and structures. Spores typically travel around 10 m, drift plants (and dislodged sporophylls) can disperse anywhere from 1 km to 10 km. However, currents and size of population can also influence spread (Forrest et al. 2000 as cited in Aquenal 2008c). Observations in Tasmania suggest that natural spread can be 5 km to 10 km/year (Sanderson 1997 as cited in Aquenal 2008c).
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	True	*U. pinnatifida* is a nuisance fouler of poorly maintained vessels and structures, but is generally perceived to be of minimal concern (Sinner et al. 2000). However, this species can foul shellfish and aquaculture structures (James & Shears 2016). *U. pinnatifida* is established only in Victoria and Tasmania, and based on sea surface temperature and temperature tolerances modelling (Richmond et al. 2010), it could spread to all jurisdictions except the Northern Territory. Task group members agreed that there is likely to be national interest in containing the species spread and improving its management.

Criterion code	Criterion	True or false	Justification
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	*U. pinnatifida* is currently in Tasmania and Victoria. A population in Apollo Bay was subject to eradication attempts. However, this was not achieved and now is being managed to reduce further spread (Australian Emergency Marine Pest Plan 2015).
1L	The species is not widely cultivated in Australia.	True	*U. pinnatifida* is commercially wild harvested in Tasmania (DPIPWE 2015).
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	True	*U. pinnatifida* is only known to be established in Tasmania and Victoria (Australian Emergency Marine Pest Plan 2015; John Lewis [APMPL task group] pers. comm.)
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	The distribution of *U. pinnatifida* is one of a well-established community along a continuous section of coastline that would be maintained by natural dispersal, then satellite populations associated with small vessel movement, as in Port Phillip Bay (John Lewis [APMPL task group] pers. comm.). New Zealand populations are reported to be associated with aquaculture facilities (James & Shears 2016b).
2	This species progresses to Step 2 (all criteria are true).	True	*U. pinnatifida* meets all criteria for Step 1.

Table G9 Step 2 assessment for *Undaria pinnatifida*

Category code	Impact category	Criterion	True, false or unknown	Justification
2-0	Impact intensity (prerequisite)	The species is likely to reach high densities and maintain its invasiveness over time.	True	Populations with seasonal high densities have established and persisted in Victoria, Tasmania, New Zealand and other parts of the world. It has invasive characteristics such as an opportunistic life history, persistent microscopic gametophyte, rapid sporophyte growth (1 cm/day) and reproductive maturation, and one plant is capable of releasing millions of spores during the reproduction period (Australian Emergency Marine Pest Plan 2015).
2A	Environmental impacts	The species negatively impacts the physical environment, biodiversity, ecological structure or function, or ecosystem services.	Unknown	Establishment is linked to environmental disturbance (Carnell & Keough 2014; South & Thomsen 2016). Ecosystem impacts have not been conclusively established (Aquenal 2008c), but possible effects through increased coastal production, export biomass and nutrient cycling (South & Thomsen 2016). It can also have positive impacts (Katsanevakis et al. 2014).
		The species is likely to lead to the extinction or significant decline of a nationally protected or endangered species or community.	False	No known evidence

Category code	Impact category	Criterion	True, false or unknown	Justification
		The species negatively impacts ecologically valuable marine species.	False	No known evidence
		The species negatively impacts places of nationally importance (relevant to the national identity).	False	No known evidence
		The species negatively impacts ecologically valuable places.	False	No known evidence
2B	Social impacts	The species negatively impacts infrastructure used by a significant proportion of people.	False	Commonly grows on jetty and wharf piles, but with no observed negative consequences (J Lewis, pers. obs.)
		The species negatively impacts amenity of resources used by a significant proportion of people over and extensive area.	False	In France, large amounts of detached plants were cast ashore in early 1990s (Katsanevakis et al. 2014). This impact has not yet been seen in Port Philip Bay.
		The species negatively impacts cultural assets valued by particular sections of the community.	False	No known evidence
2C	Business impacts	The species negatively impacts the profitability of recreational or commercial fisheries (including aquaculture).	True	It can foul shellfish and aquaculture structures (James & Shears 2016), and poorly maintained vessels and floating structures.
		The species negatively impacts the profitability of any other industry directly reliant on utilisation of and/or access to the marine environment.	True	Fouling of recreational craft.
		The species negatively impacts product acceptability in international markets and/or state/territory access to domestic markets.	False	No known evidence
		The species negatively impacts international and/or domestic shipping due to increased costs of meeting required biosecurity standards.	Unknown	Requirements to clean construction vessel hulls (such as dredging and dredging vessels) and other small vessels departing infected locations on domestic voyages would increase costs.
2D	Human health impacts	The species is likely to cause illness and/or physical injury to people resulting in deaths, permanent disabilities and/or substantial long-term health costs to the community.	False	No known evidence
3	Response	The species progress to Step 3, and recommendation for the APMPL.	True	*Undaria pinnatifida* has significant negative impacts on businesses (2C).

Table G10 Step 3 assessment for *Undaria pinnatifida*

Criterion code	Criterion	True or false	Justification
3A	There is a national control plan for the species. (If false, provide details of known control options.)	True	There is the *National Control Plan for the Japanese Seaweed, 'Undaria pinnatifida'* (Aquenal 2008c), and the *Japanese seaweed ('Undaria pinnatifida')—Australian Emergency Marine Pest Plan (EMPPlan) Rapid Response Manual* (Department of Agriculture and Water Resources 2015d).
3B	There are molecular tools for identifying the species.	True	It can be identified using DNA barcoding (Bolt & Giblot-Ducray 2011).
3C	The potential distribution of the species has been modelled.	True	The potential distribution has been modelled using the invasive marine species mapping program (Richmond et al. 2010).

Annelida

Pseudopolydora paucibranchiata

Phylum: Annelida

Common name: Japanese polydorid worm

Status: Established

Assessed by Justin McDonald; reviewed by Sarah Graham and Sandra Parsons

Table G11 Step 1 assessment for *Pseudopolydora paucibranchiata*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Pseudopolydora paucibranchiata* is not freshwater, although the species lives in estuarine environments, where reports of salinity tolerance range from 15 ppt to 37 ppt (Fofonoff et al. 2003).
1B	The species is not native.	True	*P. paucibranchiata* is not native to Australia. Its native range is Japan, and from Hong Kong to the southern Kuril Islands. Its introduced range is the north-east Pacific, Australia, New Zealand, and the north-east Atlantic (Norway to the Mediterranean) (Fofonoff et al. 2003). The first record of occurrence of *P. paucibranchiata* in Australia was in Port Phillip Bay in Victoria between 1969 and 1971, and subsequently in Jervis Bay, New South Wales in 1972 and Botany Bay in 1973 (Blake & Kudenov 1978 as cited by NIMPIS 2017m).
1C	The species is not on the EPBC Act live import list.	True	*P. paucibranchiata* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	Misidentifications often occur; for example in Turkey, *P. paucibranchiata* was misidentified as *P. antennata* (Dagli & Çinar 2008). The species is very difficult to identify in the field due to its small size (maximum length 18 mm) and its habitat where it lives in the muddy bottom of estuaries. The species needs to be identified under a high-powered microscope. However, it does not need molecular tools to identify it from natives.
1E	The species could feasibly be controlled in the environment.	False	*P. paucibranchiata* is an intertidal, infaunal species that lives in muddy habitats (Fofofnoff et al. 2003). Control of the species would be extremely hard given its cryptic nature: living in muddy environments, very small size (maximum length 18 mm) and having a very high degree of difficulty to identify without a microscope. Complete habitat smothering may be an option, although this species has never been eradicated, managed or controlled.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	Vectors include ballast water and hull fouling, and both can theoretically be managed (Hayes et al. 2005). *P. paucibranchiata* is thought to have been introduced to Turkey through larvae in ballast tanks (Dagli & Çinar 2008). However, fouling on recreational vessels would be more difficult to manage.

Criterion code	Criterion	True or false	Justification
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	False	*P. paucibranchiata* has minimal impacts through displacing other native spionid species, and was regarded as a 'Low Priority' in the CSIRO hazard rankings (Hayes et al. 2005). The species is widely established in Australia, being recorded in all jurisdictions except Tasmania (Kohn et al. 2005; ALA 2017d). The species is also reported to become invasive in more polluted habitats (see Fofonoff et al. 2003 and Dagli & Çinar 2008 for references).
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	*P. paucibranchiata* is widely established in Australia, except Tasmania. Although technically feasible to eradicate—as it is not a microscopic or mobile species—eradication is highly unrealistic. The species is very difficult to identify in the field, and its habitat of living in mud would make detections difficult at the initial incursion stage. Implementing a cost-effective approach would not be feasible, as a significant amount of both time and money would be required to eradicate this widely established species.
1L	The species is not widely cultivated in Australia.	True	Being a small Spionid worm, *P. paucibranchiata* is not a cultivated species.
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	False	*P. paucibranchiata* is recorded in all potential states and territories except Tasmania (Kohn et al. 2005; ALA 2017d). Unsure of potential for survival in Tasmania.
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	The greatest transportation vectors are ballast water and hull fouling, along with accidental introduction via oyster shells, which are the vectors cited for the species introduction to the north-eastern Pacific (Cohen & Carlton 1995).
2	This species progresses to Step 2 (all criteria are true).	False	*P. paucibranchiata* does not pass Step 1: it is difficult to identify in the field (1D); it cannot feasibly be controlled in the environment (1E); is established in all likely potential states and territories (1M); and there is unlikely to be national interest in containing the species' spread and improving its management (1J).

Sabella spallanzanii

Phylum: Annelida

Common name: European fan worm

Status: Established

Assessed by Justin McDonald; reviewed by Alicia McArdle and Sandra Parsons

Table G12 Step 1 assessment for *Sabella spallanzanii*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Sabella spallanzanii* is not a freshwater species. Adult salinity tolerances have been described between 26 ppt and 39 ppt (NIMPIS 2017p).
1B	The species is not native.	True	*S. spallanzanii* is not native to Australia. It was first found in Albany 1965, detected in Port Philip Bay by 1991, and was possibly in South Australia in the 1970s (Andrew & Ward 1997). The species' native range is Europe, where it is widespread in the Mediterranean (Spain, France, Italy and Morocco) (Andrew & Ward 1997).
1C	The species is not on the EPBC Act live import list.	True	*S. spallanzanii* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	*S. spallanzanii* can be identified (see Read et al. 2011 for summary). NIMPIS (2017p) and the Invasive Polychaete Identifier (2017) provide an overview of the morphological differences between native *Sabellastarte* spp. and *S. spallanzanii*.
1E	The species could feasibly be controlled in the environment.	True	*S. spallanzanii* is found attached to substrate, 1 m to 30 m deep, and is prevalent in harbours where it attaches to man-made structures (Andrew & Ward 1997). Aquenal (2008a) lists several options for management. However, many of these will be difficult to employ. For example, physical removal of the species, if not done properly, may lead to regeneration of the organism; and chemical control and wrapping is only feasible on man-made structures in small areas. None of these options is suitable for larger infestations. McEnnulty et al. 2001 notes that for control to be successful, the organism must be removed prior to maturity and reproduction. Control will depend on the spatial extent and will of agencies to do so. They can be controlled with expensive manual extraction from new incursions and prized areas. On a small scale, a trial of wrapping pylons with black plastic was successful (Alicia McArdle [APMPL task group] pers. comm.).
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	*S. spallanzanii* was originally thought to have been introduced to Australia as a fouling organism on ships hulls or possibly through the release of ballast carrying juveniles (Andrew & Ward 1997). These vectors may be able to be controlled. However, control of recreational vessels would be difficult, as has been demonstrated by the

Criterion code	Criterion	True or false	Justification
			detection of the species on yachts in Kangaroo Island (Kinloch et al. 2009; Alicia McArdle [APMPL task group] pers. comm.)
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	False	Workshop participants determined that, as *S. spallanzanii* is established in all potential jurisdictions where it could occur (although it has not established in Tasmania, it has been recorded there), there is likely no national interest in containing the species spread and improving its management.
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	*S. spallanzanii* has been in Australia for many years; these established populations are not feasible to eradicate. The species is still present in Eden, New South Wales, even after eradication attempts (Murray & Keable 2013).
1L	The species is not widely cultivated in Australia.	True	*S. spallanzanii* is not a cultivated species.
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	True	*S. spallanzanii* has been documented in Western Australia, South Australia, Victoria and New South Wales (ALA 2017e) and has been recorded in Tasmania (NIMPIS 2017p). According to modelling of the species potential range in Australia, the species has been detected in all potential jurisdictions (Richmond et al. 2010). However, the species has not established in Tasmania.
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	*S. spallanzanii* is spread by ballast water and hull fouling (Aquenal 2008a). The introduction of *S. spallanzanii* to New Zealand is also thought to have occurred via hull fouling or ballast (Read et al. 2011) from the southern Australia population (Ahyong et al. 2017). There is no understanding of the natural dispersal capabilities of the species, and human mediated dispersal is likely to be the most likely pathway of introduction to new areas.
2	This species progresses to Step 2 (all criteria are true).	False	*S. spallanzanii* does not pass Step 1: there is unlikely to be national interest in containing the species' spread and improving its management (1J).

Arthropoda

Amphibalanus eburneus

Phylum: Arthropoda

Common name: Ivory barnacle

Status: Exotic

Assessed by John Lewis; reviewed by Jessica Evans

Table G13 Step 1 assessment for *Amphibalanus eburneus*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Amphibalanus eburneus* is a marine species. It is a polyhaline species (Dineen & Hines 1994) with a wide salinity tolerance, found in waters between 5 ppt and 30 ppt (as cited in Sweat 2009). Under laboratory conditions, settlement can occur at salinities between 2 ppt and 35 ppt, but highest rates occur between 15 ppt and 20 ppt (Dineen & Hines 1994).
1B	The species is not native.	True	*A. eburneus* is native to the Atlantic coast of North America and the Caribbean to northern South America, and is considered to be distributed worldwide in warm and tropical seas (Hawaii Biological Survey 2001). There are no records of its presence in Australia, despite being a common fouler of international ships (Inglis et al. 2010).
1C	The species is not on the EPBC Act live import list.	True	*A. eburneus* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	*A. eburneus* is a small barnacle, but is reasonably distinctive in having a white shell with no stripes. Opercular plates also reasonable distinctive. It can be confused with the exotic *Amphibalanus improvisus* (Sweat 2009).
1E	The species could feasibly be controlled in the environment.	False	Individuals or patches of barnacles on structures could be mechanically removed or crushed if immature. Management of post reproductive *A. eburneus* populations is unlikely due to planktonic larval stages and distribution in water currents.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	Biofouling prevention or restrictions on vessel movements could feasibly reduce the interregional, but not local or regional spread of this species due to the planktonic distribution of larvae.
Exotic species screening			

Criterion code	Criterion	True or false	Justification
1G	The species is not known to be present in Australian waters.	True	There are no known reports or records of *A. eburneus* in Australia.
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	*A. eburneus* is a common fouler on international ship hulls; the 6th most common species detected on international merchant vessels surveyed in New Zealand; on 6% of vessels (Inglis et al. 2010). It has been known as a fouler of international ships for more than 150 years (Darwin 1854; Pilsbry 1916; Bishop 1951; Southward & Crisp 1963).
1I	The species has the potential to become established in Australian waters	True	The temperature tolerance of *A. eburneus* is thought to be quite wide given its distribution throughout temperate and tropical latitudes. Salinity tolerance is also quite wide, found in waters between 5 ppt and 30 ppt (as cited in Sweat 2009). Under laboratory conditions, settlement can occur between a salinity of 2 ppt and 35 ppt, but highest rates occur between 15 ppt and 20 ppt (Dineen & Hines 1994). The environment in Australia is considered suitable for establishment, but colonisation and establishment is uncertain, as it is likely to have been regularly present on hulls of visiting ships over many decades but has not yet established.
2	This species progresses to Step 2 (all criteria are true).	False	*A. eburneus* does not pass Step 1: it could not feasibly be controlled in environment (1E).

Amphibalanus improvises

Phylum: Arthropoda

Common name: Bay barnacle

Status: Established

Assessed by Richard Willan; reviewed by Sandra Parsons

Table G14 Step 1 assessment for *Amphibalanus improvises*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	All stages of the *Amphibalanus improvisus* life cycle are marine. However, it is particularly tolerant of brackish waters, as it can osmoregulate when acclimation time is sufficient (Furlani 1996). Cyprid larvae are able to metamorphose in freshwater (0 ppt) (Furlani 1996). It has invaded several brackish seas (Caspian, Black and Baltic) and whilst it can tolerate a wide range of salinities, it does best in low salinity waters (see Wrange et al. 2016).
1B	The species is not native.	True	*A. improvisus* is not native to Australia. It was reported by Bishop (1951) from southern Western Australia, but there are apparently no further records from Australia (Furlani 1996). Hayes et al. 2005 included it in their list

Criterion code	Criterion	True or false	Justification
			of introduced and cryptogenic species in Australian marine waters. Naser et al. (2015) report the species as established in Australia and therefore we accept the conclusion and treat it as an established species. Its native range is the temperate North Atlantic Ocean (North America and Europe). Introduced to Japan and Pacific North America, probably by hull fouling and oyster mariculture (1890s to 1930s) (Furlani 1996).
1C	The species is not on the EPBC Act live import list.	True	*A. improvisus* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	*A. improvisus* was diagnosed by Furlani (1996), and it would be able to be distinguished with Australian natives in the field. Its shell plates are white. The radii overlap the alae. Tergal plates with convex carinal margin, with open spur furrow, spur length greater than width.
1E	The species could feasibly be controlled in the environment.	False	*A. improvisus* can survive in mangrove forests and subtidally to 46 m, so control in the wild would probably be impossible. There are no references to the species being controlled in the environment.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	*A. improvisus* is a common ship-fouling organism, and its long distance dispersal can largely be attributed to shipping (Wrange et al. 2016). Fouling of ships could feasibly be managed in an incursion. However, Wrange et al. (2016) postulates that natural larval dispersal may also play an important role in the distribution of the species following its initial introduction into a location, suggesting the species would be difficult to manage after establishment.
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	False	Probably not, since *A. improvisus* may have been established in Australia since the 1950s. There is also no strong evidence for its impact.
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	*A. improvisus* was reported by Bishop (1951) from southern Western Australia, but no further records from Australia (Furlani 1996). Hayes et al. 2005 included it in their list of introduced and cryptogenic species in Australian marine waters, while Naser et al. (2015) report the species as established in Australia.
1L	The species is not widely cultivated in Australia.	True	*A. improvisus* is not a cultivated organism.
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	True	*A. improvisus* was reported by Bishop (1951) from southern Western Australia, but no further records from Australia (Furlani 1996). Hayes et al. 2005 included it in their list of introduced and cryptogenic species in Australian marine waters, while Naser et al. (2015) report the species as established in Australia.

Criterion code	Criterion	True or false	Justification
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	*A. improvisus* is a common ship-fouling organism and its long distance dispersal can largely be attributed to shipping (Wrange et al. 2016). The species is a common ship barnacle, and was found on 18% of 270 vessels coming to New Zealand (John Lewis [APMPL task group] pers. comm.).
2	This species progresses to Step 2 (all criteria are true).	False	*A. improvisus* does not pass Step 1: it cannot feasibly be controlled in the environment (1E); pathways and vectors cannot feasibly be managed (1F); and there is unlikely to be national interest in containing the species' spread and improving its management (1J).

Austromegabalanus psittacus

Phylum: Arthropoda

Common name: Picoroco

Status: Exotic

Assessed by John Lewis; reviewed by Jessica Evans

Table G15 Step 1 assessment for *Austromegabalanus psittacus*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Austromegabalanus psittacus* is a marine species, inhabiting intertidal and subtidal rocky shores (as cited in Simpfendorfer et al. 2006).
1B	The species is not native.	True	*A. psittacus* is exotic to Australia, and is not listed on the Atlas of Living Australia (ALA 2017b). It is native to the Chilean and Peruvian coastlines (as cited in Simpfendorfer et al. 2006). The only area this species had been recorded outside of its native range is one population in New Zealand (Biosecurity New Zealand 2007).
1C	The species is not on the EPBC Act live import list.	True	*A. psittacus* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	*A. psittacus* would be difficult to distinguish from the native barnacle *Austromegabalanus nigrescens* without dissection of the opercular plates for examination of internal surfaces. Differences are: • *A. psittacus*—Adductor ridge of scutum confluent with articular ridge. Shell white-pink. • *A. nigrescens*—Adductor ridge of scutum separate from articular ridge. Shell whitish-blue to purple, often darker when eroded (Hosie & Ahyong 2008).
1E	The species could feasibly be controlled in the environment.	True	Localised populations of *A. psittacus* could be manually removed or, if immature, crushed.

Criterion code	Criterion	True or false	Justification
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	Introduction in New Zealand is thought to have occurred via biofouling on a ship. Vectors can theoretically be managed (Hayes et al. 2005).
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*A. psittacus* not present in Australia. The species has only been recorded outside of its native range in New Zealand (Biosecurity New Zealand 2007).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	The small population of *A. psittacus* found in New Zealand is considered likely to have been introduced in a single arrival as biofouling on a ship (Hosie & Ahyong 2008). Charles Darwin also refers to specimens collected off a ship. The related Australian species *A. nigrescens*, which similarly grows on exposed rocky shores with heavy wave action (Poore & Syme 2009) is known to foul ships in eastern Australia (John Lewis, pers. obs.) and an alien population has established at Taharoa Terminal in New Zealand (Hosie & Ahyong 2008). *A. psittacus* was not one of the 50 acorn barnacle species detected on international vessels entering NZ waters, although *A. nigrescens* was, so its colonisation of vessels is not common (Inglis et al. 2010).
1I	The species has the potential to become established in Australian waters	True	*A. psittacus* occupies a similar latitude range to eastern Australia, and suitable habitat of high-energy rocky shores is abundant. However, the absences of established populations outside of its native range does not indicate it to be a highly invasive species. New Zealand has the only introduction (Biosecurity New Zealand 2007).
2	This species progresses to Step 2 (all criteria are true).	False	*A. psittacus* does not pass Step 1: it would be difficult to accurately identify in the field (1D).

Balanus glandula

Phylum: Arthropoda

Common name: Common acorn barnacle

Status: Exotic

Assessed by Richard Willan; reviewed by Sandra Parsons

Table G16 Step 1 assessment for *Balanus glandula*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Balanus glandula* is marine for its entire life cycle (Morris et al. 1980). It has been characterised morphologically by Mendez et al. (2013). Its reproduction and growth have been described by Berger et al. (2006).
1B	The species is not native.	True	*B. glandula* is not native to Australia or established. The species is native to the west coast of North America, and has invaded Japan, South Africa and Argentina (Kado 2003; Simon-Blecher et al. 2008; Savoya & Schwindt 2010).
1C	The species is not on the EPBC Act live import list.	True	*B. glandula* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	*B. glandula* is not easy to identify or distinguish from native barnacles in the field, particularly from the six-plated barnacle *Chthamalus antennatus* which occurs in the upper intertidal on rocky shores across south-eastern Australia from Queensland to Western Australia (Poore & Syme 2009). It was first formally recorded from the cool-temperate west coast of South Africa in 2008; although photographic evidence suggests it was common there for at least the previous 15 years, but had been misidentified as the indigenous *Chthamalus dentatus* (Griffiths 2011). Similarly, Schwindt (2007) suggested that the invasion of *B. glandula* in Argentina went overlooked and most likely occurred prior to its report in 2003.
1E	The species could feasibly be controlled in the environment.	False	*B. glandula* inhabits the undeveloped intertidal zone of rocky shores. Mendez et al. (2013) emphasised that soft-bottom environments, where some hard substrates are available, have to be seriously considered when designing early detection plans targeting *B. glandula*. No control options for the species are feasible.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	Domestic spread of *B. glandula* would be highly feasible. It is likely that the species would not be detected until it has already established, and its similarity to natives mean that control of pathways would not easily be managed to further prevent the species spread.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	It is not known in Australian waters.

Criterion code	Criterion	True or false	Justification
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	*B. glandula* was transported to Argentina in the 1970s, South Africa in the early 1990s and Japan in the last 20–40 years (see Kado 2003; Simon-Blecher et al. 2008). It is thought to have been spread by ships to Japan (Kado 2003) and Argentina (Geller et al. 2008). Mead et al. (2011) considered ship fouling the most likely introduction of the species to South Africa.
1I	The species has the potential to become established in Australian waters	True	*B. glandula* tolerates a wide range of temperatures in its native and introduced regions (Schwindt 2007), it is found in the cold temperate waters of Argentina, Japan and South Africa (Simon-Blecher et al. 2008).
2	This species progresses to Step 2 (all criteria are true).	False	*B. glandula* does not pass Step 1: it would be difficult to accurately identify in the field (1D); it could not feasibly be controlled in the environment (1E); and pathways and vectors could not feasibly be managed (1F).

Callinectes sapidus

Phylum: Arthropoda

Common name: Atlantic blue crab

Status: Exotic

Assessed by Alex Chalupa; reviewed by Jessica Evans

Table G17 Step 1 assessment for *Callinectes sapidus*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Callinectes sapidus* is a diadromous species (NIMPIS 2017b). The species is reported as euryhaline and lives in estuaries and marine embayments on muddy and sandy bottoms (Hill et al. 1989 as cited in Stasolla & Innocenti 2014). In its native range, it has been reported to live in freshwater in rivers to near ocean salinity (34 ppt) (Hill et al. 1989 as cited in Nehring 2012).
1B	The species is not native.	True	*C. sapidus* is not native to Australia and there are no records of this species being present in Australia (NIMPIS 2017b). It is native to the United States, Canada, parts of Central and South America (Hill 2004). The species has been introduced to European counties including France, Denmark, Netherlands, Germany, Belgium, Spain, Portugal, Greece and Italy (Jensen 2010a).
1C	The species is not on the EPBC Act live import list.	True	*C. sapidus* is not listed on the EPBC Act live import list.
1D	The species is:	True	The species can be identified with a high degree of taxonomic certainty. *C. sapidus* is a decapod crustacean of the family Portunidae. It can be identified by the bright blue colour along the frontal area, especially along the chelipeds, and grey/green/brown colour on the remainder of the body. Carapace on average is 17 cm.

Criterion code	Criterion	True or false	Justification
	• identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.		However, much larger crabs with a carapace of 27 cm have been found. As with other Portunids, the fifth leg is adapted to a paddle-like shape to accommodate swimming. Females can be distinguished from males by the red or orange fingers on the chelae and triangular or round aprons (Hill 2004; Jensen 2010a). The species is distinguishable from native blue swimmer crabs (*Portunus armatus*) although very similar (Alex Chalupa, pers. comm.).
1E	The species could feasibly be controlled in the environment.	True	There is potential to do large-scale fishing for *C. sapidus* to minimise numbers. It is a major commercial species in its home range and populations have been impacted by fishing pressure (Bourgeois et al. 2014). The species spawns 2 million to 6 million eggs per brood. However, on average, only 1 out of every million eggs survives to become a mature adult (Nehring 2012). The species can have multiple broods in a year. The planktonic larval stage lasts between 31 days and 49 days. Adults, particularly females, are also great dispersers (can swim hundreds of kilometres) (Nehring 2012). Controlling abundances could be difficult given dispersal, high fecundity and planktonic larval stages. Control in some habitats may be difficult, particularly since *C. sapidus* inhabits estuaries and shallow coastal waters to 90 m depth, and soft sediments would make the crab difficult to collect. There is a low probability of eradicating this species if it were to establish.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	Holthuis & Gottlieb (1958) and Nehring (2011) suggested that *C. sapidus* arrived into the Mediterranean in ballast tanks (as cited in Razek et al. 2016). Ballast could feasibly be managed to prevent the spread of this species. Hull fouling is also a potential mechanism for regional spread.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	There are no records of *C. sapidus* being present in Australia (NIMPIS, 2017b).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	There is potential for *C. sapidus* to spread (Brockerhoff & McLay 2011) and it could arrive potentially in ballast. Larval development is 37 to 69 days (Hill et al. 1989) which makes vessel transport plausible (Nehring 2012). Nehring (2012) notes that the species was unlikely to be transported long distances on ships hulls because of its affinity to brackish water. There is also the possibility for intentional introduction as it is a highly valued seafood.
1I	The species has the potential to become established in Australian waters	True	Similar species exist in Australia and matches known areas for climate (has been recorded in similar climatic regions) (CIESM 2006). Also, given that *C. sapidus* also has a wide temperature range of between 3 °C and 37 °C (NIMPIS 2017b), it may be likely to establish in Australian waters.
2	This species progresses to Step 2 (all criteria are true).	False	Callinectes sapidus does not pass Step 1: pathways and vectors could not feasibly be managed (1F).

Caprella mutica

Phylum: Arthropoda

Common name: Japanese skeleton shrimp

Status: Exotic

Assessed by Michelle Besley; reviewed by Jessica Evans

Table G18 Step 1 assessment for *Caprella mutica*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Caprella mutica* is a marine amphipod crustacean indigenous to eastern Asia (Boos et al. 2011).
1B	The species is not native.	True	*C. mutica* is not native or known in Australia. It is native to north-east Asia, along the Russian coasts of the Sea of Japan and the Japanese archipelago (Schurin 1935; Arimoto 1976; Fedotov 1991; Vassilenko 2006; as cited in Boos et al. 2011). Caprella mutica has become successfully established throughout the temperate northern hemisphere and in New Zealand in the southern hemisphere (Boos et al. 2011).
1C	The species is not on the EPBC Act live import list.	True	*C. mutica* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	*C. mutica* is strongly diverged from the typical gammarid amphipod morphology. Caprellid amphipods are recognized by their elongated bodies and a reduction in the number and type of appendages (Hayward & Ryland 1996 as cited in Boos et al. 2011). *C. mutica* are larger than other caprellids. However, as they are still very small (average length is 25–30 mm for males, 15–20 mm for females) (Boos et al. 2011), it is unlikely that they would be identified in the field to the species level (Jensen 2010b). As such, it is also unlikely that *C. mutica* and native/naturalised species in Australia could be distinguished from each other. It has also been suggested by Boos et al. (2011) that it may be difficult to identify an introduced population due to the species inconspicuousness (small populations in certain habitats), seasonal variation in populations, and potentially the absence of taxonomic expertise and surveying.
1E	The species could feasibly be controlled in the environment.	False	There have been no efforts to eradicate *C. mutica* from established sites and therefore control methods such as using freshwater (shallow areas with freshwater input), aerial exposure, traps and/or pheromones have not been tested as yet (Boos et al. 2011). The species can travel small distances for some limited natural dispersal (found to disperse up to 1 km) (Boos et al. 2011). Given its high fecundity, fast growth and ability to disperse, it is unlikely to reduce numbers once it is established.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	*C. mutica* can be found in abundance on boat hulls, floating pontoons and aquaculture infrastructure (Boos et al. 2011). It can also be spread via ballast. Ballast water, oyster/aquaculture equipment, boating could be feasibly managed to limit the spread of this species. However, some individuals are thought to drift on algae

Criterion code	Criterion	True or false	Justification
			(Boos et al. 2011). Natural dispersal is also thought to have been responsible for local spread of this species—via either natural currents or its ability to swim short distances—with *C. mutica* observed 1 km from the source population (Boos et al. 2011).
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	It is not present in Australia (Boos et al. 2011).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	Long-distance introductions of *C. mutica* are most likely a consequence of increased global and local shipping traffic (transit in ballast water or on fouled boat hulls). This is in addition to co-transports of introduced aquaculture organisms, such as the Pacific oyster (*Magallana gigas*) native to the Sea of Japan (Takeuchi & Sawamoto 1998; Cohen & Carlton 1995; Gollasch et al. 2002; Tierney et al. 2004; Ashton et al. 2006; as cited in Boos et al. 2011).
1I	The species has the potential to become established in Australian waters	True	*C. mutica* has established in New Zealand, and Boos et al. (2011) suggests southern Australia would be suitable for establishment of this species. Temperature in its native range can vary between −1.8 °C and 25 °C (Schevschenko et al. 2004 as cited in Boos et al. 2011).
2	This species progresses to Step 2 (all criteria are true).	False	*C. mutica* does not pass Step 1: it would be difficult to accurately identify in the field (1D); and it could not feasibly be controlled in the environment (1E).

Carcinoscorpius rotundicauda

Phylum: Arthropoda

Common name: Mangrove horseshoe crab

Status: Exotic

Assessed by Sarah Graham; reviewed by Jessica Evans

Table G19 Step 1 assessment for *Carcinoscorpius rotundicauda*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Carcinoscorpius rotundicauda* inhabits muddy areas, commonly in brackish waters (Cartwright-Taylor et al. 2011).
1B	The species is not native.	True	*C. rotundicauda* is not native to Australia. It is native to the Central Indian Ocean, East Asian seas and north-west Pacific (Hewitt et al. 2011; Tanacredi et al. 2009).

Criterion code	Criterion	True or false	Justification
1C	The species is not on the EPBC Act live import list.	True	*C. rotundicauda* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	There are four species of horseshoe crabs; none native to Australia (Tanacredi et al. 2009). Therefore, *C. rotundicauda* is likely to be identified should it arrive in Australia and would be distinguishable from native crabs.
1E	The species could feasibly be controlled in the environment.	False	*C. rotundicauda* does not move out to sea with the receding tide, therefore dispersal is likely low. Instead, adults can be found buried from 2 cm to 3 cm deep in the wet mud, while sub-adults and juveniles remain on the surface (Cartwright-Taylor et al. 2011). The species should be able to control in shallow water, but may be difficult given it buries itself in the substrate.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	The spread of *C. rotundicauda* is thought to be possibly through ballast water and/or biofouling of vessels (Hewitt et al. 2011).
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	The only documented detection of *C. rotundicauda* as introduced was one instance in New Zealand in 1910 (Ahyong & Wilkens 2011 as cited in McDonald et al. 2015).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	Transport Pressure Rank for *C. rotundicauda* is listed as high (Hewitt et al. 2011), given the trade with International Union for Conservation of Nature (ICUN) bioregions where the species occurs. The species is thought to be transported potentially through biofouling or ballast water (Hewitt et al. 2011). However, the only introduction of this species of horseshoe crab was to New Zealand in 1910 (Cranfield et al. 1998).
1I	The species has the potential to become established in Australian waters	True	The physiological temperature tolerance of *C. rotundicauda* is 22 °C to 35 °C (moulting occurs when temperatures are over 28 °C, and stops if temperatures drop below 22 °C) (Hewitt et al. 2011). It feeds mostly on small fish and invertebrates, and inhabits brackish/mangrove areas. Therefore, the species could potentially establish in Australia.
2	This species progresses to Step 2 (all criteria are true).	False	*C. rotundicauda* does not pass Step 1: it could not feasibly be controlled in the environment (1E).

Carcinus maenas

Phylum: Arthropoda

Common name: European green crab

Status: Established

Assessed by Tim Glasby; reviewed by Jessica Evans

Table G20 Step 1 assessment for *Carcinus maenas*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Carcinus maenas* is tolerates salinities from 1.4 ppt to 54 ppt and a range of habitats including intertidal and shallow subtidal of bays, estuaries and open coasts (NIMPIS 2017c).
1B	The species is not native.	True	*C. maenas* is not native to Australia. The species was recorded in Port Phillip Bay in 1900 (Fulton & Grant 1900) where 'a number of specimens' were evidently found. Fulton & Grant (1902) described it as exceedingly abundant and cited Allcock (1899) as documenting an even earlier unconfirmed report of its occurrence in Australia. Fulton & Grant (1902) went on to say that other authors had speculated that it was actually first introduced into Australia in the 1850s via lumber ships.
1C	The species is not on the EPBC Act live import list.	True	*C. maenas* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	*C. maenas* is identifiable with a high degree of taxonomic certainty and is distinguishable from natives in the field. It is a medium-sized crab growing to a width of 8 cm to 9 cm across the carapace. It has five distinct spines on both sides of the carapace near the eyes. The fourth walking leg has no swimming paddle. The colour does vary intraspecifically, but is usually green, and there can be red/orange markings on the ventral side particularly in larger crabs (NIMPIS 2017c).
1E	The species could feasibly be controlled in the environment.	True	A new incursion or significant range extension of *C. maenas* could be controlled if individuals were removed before they could breed and establish a population. Adults and juveniles can be caught in traps and spat collectors can be used to sample newly settled juveniles (Garside et al. 2015), but these techniques are unlikely to be useful methods for controlling if in high abundance (Aquenal 2008b). There is a national control plan for *C. maenas*, which concludes that 'Control of *C. maenas* in high risk source regions should only be considered if the risk is associated with human mediated transport (such as ballast water or aquaculture activities).'
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	The primary anthropogenic vectors for *C. maenas* are ballast water and aquaculture stock (such as oysters), or by individuals using the species as food or bait. These vectors are theoretically manageable (via ballast water management, and communication and awareness campaigns) and as such, human mediated transport to a new jurisdiction in Australia (only Western Australia is relevant) could be managed. Being a broadcast

Criterion code	Criterion	True or false	Justification
			spawner (planktonic larval duration is approximately 30–50 days; deRivera et al. 2007), natural dispersal is likely to contribute substantially to its spread, but control of natural dispersal from established populations is likely to be impractical or impossible. However, natural spread to Western Australia from current infestation in other states is extremely unlikely.
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	True	Western Australia is the only new state where *C. maenas* is likely to invade; it has not yet invaded all potential areas in South Australia. Spread within existing jurisdictions can mostly occur via natural dispersal. In South Australia, *C. maenas* is limited to the same-risk areas comprising Gulf St Vincent and Spencer Gulf, and the domestic ballast water arrangements contribute to preventing its spread to the West Coast where the *Katelysia* spp. (hard-shell cockle) fishery is located.
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	*C. maenas* is established in South Australia, Victoria, Tasmania, and New South Wales. Removal efforts in New South Wales had little effect on abundance and the species has now been recorded from 28 estuaries in that state (Tim Glasby [APMPL task group] pers. comm.).
1L	The species is not widely cultivated in Australia.	True	A small commercial trap fishery exists for *C. maenas* in the Gippsland Lakes area of Victoria (Bill Lussier, pers. comm.)
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	True	*C. maenas* is present in South Australia, Victoria, Tasmania, and New South Wales. It is not known to be established in Western Australia (Wells & McDonald 2007), although one individual was collected there in 1965 (Zeidler 1978). BRS temperature modelling suggests it could establish there (Richmond et al. 2010). In contrast, Poore considers that water temperature has possibly prevented establishment in Western Australia.
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	Western Australia is the only jurisdiction in which *C. maenas* could potentially survive, but is not yet established. Given the closest known population to Western Australia is Port Adelaide, it seems very unlikely that there would be natural dispersal from here to Western Australia given the direction of the dominant coastal currents. Natural dispersal of *C. maenas* can occur over hundreds of kilometres (Shanks et al. 2003). Larvae leave their natal estuary and can travel approximately 40 km offshore (Queiroga 1996) and can remain in the plankton for 30days to 50 days (deRivera et al. 2007). Its occurrence in New South Wales estuaries that have no aquaculture and which, due to their size and remoteness, could only be visited by small trailer boats (not vectors for the species) suggests that natural dispersal is the most likely way it could have arrived in these estuaries. Oceanographic modelling supports this conclusion (Roughan et al. 2011), as do the opening regimes of New South Wales lagoons (Garside et al. 2014) and genetic studies of connectivity (Burden et al. 2014).
2	This species progresses to Step 2 (all criteria are true).	True	*C. maenas* meets all criteria for Step 1.

Table G21 Step 2 assessment for *Carcinus maenas*

Category code	Impact category	Criterion	True, false or unknown	Justification
2-0	Impact intensity (prerequisite)	The species is likely to reach high densities and maintain its invasiveness over time.	True	*Carcinus maenas* has been present in large numbers in Victoria for over 100 years. Populations fluctuate in South Australia, but each peak appears to involve higher population densities and a more extensive distribution than the previous one (M. Deveney, pers. comm.).
2A	Environmental impacts	The species negatively impacts the physical environment, biodiversity, ecological structure or function, or ecosystem services.	Unknown	*C. maenas* has negative impacts on a range of native Australian bivalve species (Walton et al. 2002; Ross et al. 2004; Tan & Beal 2015), some of which are exploited commercially. It may also reduce the abundance of seagrass (Zostera sp.) (Garbary et al. 2014; Neckles 2015). Matheson et al. (2016) used a correlative study to examine changes in seagrass abundance from before to after *C. maenas* invasion at impact and control sites. Few control sites were studied, but they reported a 50% decline in eelgrass percent cover since 1998 at sites with *C. maenas*, and eelgrass declines up to 100% at sites with the highest abundances and longest established presence of the crabs. There was a concomitant decline in fish biomass where seagrass was lost. There are a limited number of impact studies in Tasmania, where there have been significant negative impacts on native bivalve and crab populations in soft sediment habitats (Ross et al. 2004). In Tasmania, the species reduced the abundance of juvenile *Fulvia tenuicostata* (a soft-shelled bivalve) by approximately 50%, but the effect was not statistically significant. There was no effect of predation by *C. maenas* on overall assemblage of bivalves, echinoids and polychaetes (Ross et al. 2004). Walton et al. (2002) reported a trend for decreased juvenile (less than 13 mm shell length) abundance of the stepped venerid clam (*Katelysia scalarina*) at sites with *C. maenas,* relative to those without the crab. Relative predation intensity on juvenile clams was significantly higher in invaded areas. Manipulative experiments revealed that: • large *C. maenas* were the most significant predators • the smallest size class of *K. scalarina* tested (6–12 mm) was preferred by *C. maenas* • *C. maenas* had much higher predation rates than any native predator tested • *C. maenas* significantly increased its per capita predation with increasing prey density, unlike the native shore crab, *Paragrapsus gaimardii*, which had a constant predation rate over different densities of juvenile *K. scalarina*. Field experiments at Port Gawler in South Australia have shown a decrease in soft-shelled bivalves (*Mytilus galloprovincialis*). This was supported by further tests,

Category code	Impact category	Criterion	True, false or unknown	Justification
				finding that blue mussels (*M. galloprovincialis*) and juvenile mud cockles (*Katelysia* spp.) are within the range of crushing force reported for *C. maenas* (Sabine Dittmann, pers. Comm.). However, there is uncertainty regarding the impact on the industry harvesting blue mussels because they are grown on lines suspended above the bottom.
		The species is likely to lead to the extinction or significant decline of a nationally protected or endangered species or community.	False	There is no documented interaction between *C. maenas* and listed species.
		The species negatively impacts ecologically valuable marine species.	False	There is some possibility of impacts to seagrasses (Zostera), but no evidence of this occurring in Australia.
		The species negatively impacts places of nationally importance (relevant to the national identity).	Unknown	No known evidence.
		The species negatively impacts ecologically valuable places.	Unknown	No known evidence.
2B	Social impacts	The species negatively impacts infrastructure used by a significant proportion of people.	False	No known evidence.
		The species negatively impacts amenity of resources used by a significant proportion of people over and extensive area.	False	No known evidence.
		The species negatively impacts cultural assets valued by particular sections of the community.	False	No known evidence.
2C	Business impacts	The species negatively impacts the profitability of recreational or commercial fisheries (including aquaculture).	True	*C. maenas* is likely to affect bivalve populations subject to recreational harvest and aquaculture (Walton et al. 2002; Lovell et al. 2007; McKindsey et al. 2007; Tan & Beal 2015). Field experiments at Port Gawler have shown a decrease in benthic soft-shelled bivalves; this was supported by further tests, where it was found that *M. galloprovincialis* and also juvenile *Katelysia* spp. are within the range of crushing force reported for *C. maenas* (Sabine Dittmann, pers. comm.). Both *Katelysia* spp. and *M. galloprovincialis* are valuable wild fisheries in southern Australia and are normally benthic species that are likely to incur substantial impacts from invasion. *M. galloprovincialis* are cultured on hanging ropes, not on benthic surfaces, and so are less likely to be affected by *C. maenas* invasion.

Category code	Impact category	Criterion	True, false or unknown	Justification
				C. maenas can recruit into oyster trays or tumblers near the surface of the water where they consume juvenile oysters. Although the impacts of predation by *C. maenas* have not been compared to predation by other (native) crabs, interviews with oyster farmers indicate that up to 30% of stock inside trays and/or tumblers may be consumed by *C. maenas* in some New South Wales south coast estuaries (Epe 2012). It should be noted that some oyster growers did not report any effects of *C. maenas* on oysters. Business impacts for C. maenas in South Australia have not been documented or investigated, and there is currently no supporting evidence documented in Victoria.
		The species negatively impacts the profitability of any other industry directly reliant on utilisation of and/or access to the marine environment.	False	No known evidence.
		The species negatively impacts product acceptability in international markets and/or state/territory access to domestic markets.	Unknown	No known evidence.
		The species negatively impacts international and/or domestic shipping due to increased costs of meeting required biosecurity standards.	Unknown	*C. maenas* is a relevant species in ballast-water exchange protocols.
2D	Human health impacts	The species is likely to cause illness and/or physical injury to people resulting in deaths, permanent disabilities and/or substantial long-term health costs to the community.	Unknown	No known evidence.
3	Response	The species progress to Step 3, and recommendation for the APMPL.	True	*C. maenas* has significant negative impacts on businesses (2C).

Table G22 Step 3 assessment for *Carcinus maenas*

Criterion code	Criterion	True or false	Justification
3A	There is a national control plan for the species. (If false, provide details of known control options.)	True	There is the *National Control Plan for the European Green Crab, 'Carcinus maenas'* (Aquenal 2008b), and the *European Green Crab, ('Carcinus maenas')—Australian Emergency Marine Pest Plan (EMPPlan) Rapid Response Manual* (Department of Agriculture and Water Resources 2015c).
3B	There are molecular tools for identifying the species.	True	The assay described in Bott & Giblot-Ducray (2011) was partially field validated by Deveney et al. (2017).
3C	The potential distribution of the species has been modelled.	True	The potential distribution of *C. maenas* has been modelled using the invasive marine species mapping program (Richmond et al. 2010).

Charybdis japonica

Phylum: Arthropoda

Common names: Lady crab, Asian paddle crab

Status: Exotic

Assessed by Tim Glasby; reviewed by Jessica Evans

Table G23 Step 1 assessment for *Charybdis japonica*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Charybdis japonica* is a marine species (Poore 2004). Adult salinity range is 14 ppt to 33 ppt (NIMPIS 2017d).
1B	The species is not native.	True	*C. japonica* is not native to Australia. The species' native distribution is East Asia (Japan, China, Taiwan and South Korea) (Wong et al. 2016). It has been introduced to north-eastern New Zealand (Wong et al. 2016).
1C	The species is not on the EPBC Act live import list.	True	*C. japonica* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	However, there are many native species of *Charybdis* in Australia and, depending on the jurisdiction, positive identification in the field could be difficult (Poore 2004). There are molecular markers available for the species (Smith et al. 2003; Wong et al. 2016).

Criterion code	Criterion	True or false	Justification
1E	The species could feasibly be controlled in the environment.	True	*C. japonica* can be caught in traps (Archdale et al. 2007; Fowler & McLay 2013), but this may not be effective for controlling abundances because the species is a broadcast spawner (planktonic larval duration is approximately 17 days) and natural dispersal would be great (see Fowler & McClay 2013). Control is theoretically possible if the population is small; there is a national control plan for a similar broadcast spawning crab (*Carcinus maenas*). In New Zealand, the population established rapidly after it was introduced to the country (Gust & Inglis 206). Control using trapping has not been successful in New Zealand (Golder Associates 2008). Investigations are currently underway into species-specific sex pheromones to increase trap yields and destabilise populations (cited in Ahyong & Wilkens 2011).
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	*C. japonica* is a broadcast spawner (planktonic larval duration is approximately 17 days) and natural dispersal would be great (see Fowler & McClay 2013). If this natural vector does not exist (crabs controlled before reproductive event), then it might be possible to control anthropogenic vectors. Known vectors include fouling and ballast (NIMPIS 2017d), which can theoretically be controlled.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	In December 2000, a single mature male specimen of *C. japonica* was found in the Port River of Adelaide, South Australia. Despite further intensive searches, no additional specimens were collected from this location (Poore 2004). Two individuals were caught in Western Australia (2010 and 2012) (Hoursten et al. 2015). However, it is unclear if these species have established. Therefore, the species is considered as exotic.
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	*C. japonica* is native to Asia and introduced to New Zealand (Wong et al. 2016). There are numerous shipping vectors connecting Australia to these areas (Glasby & Lobb 2008; Bridgwood & McDonald 2014). Known vectors include ballast and fouling, therefore could feasibly arrive in Australia (NIMPIS 2017d).
1I	The species has the potential to become established in Australian waters	True	Two individuals were caught in Western Australia in 2010 and 2012 (Hoursten et al. 2015). However, it is unclear if these species have established. *C. japonica* has the potential to establish in Australia given its wide temperature tolerances (4 °C to 34 °C) and reproductive temperature range (20 °C to 28 °C) (NIMPIS 2017d).
2	This species progresses to Step 2 (all criteria are true).	True	*C. japonica* meets all criteria for Step 1.

Table G24 Step 2 assessment for *Charybdis japonica*

Category code	Impact category	Criterion	True, false or unknown	Justification
2-0	Impact intensity (prerequisite)	The species is likely to reach high densities and maintain its invasiveness over time.	Unknown	Difficult to say.
2A	Environmental impacts	The species negatively impacts the physical environment, biodiversity, ecological structure or function, or ecosystem services.	Unknown	Gust & Inglis (2006) speculated, '*C. japonica* could be a significant predator of small bivalves in New Zealand estuaries'. Lab experiments by Fowler et al. (2013) showed that *C. japonica* could outcompete the native *Ovalipes catharus* when competing for a single food source (*Perna canaliculus*). Wong et al. (2016) suggest that the hypothesised impacts of *C. japonica* in New Zealand (only known incursion of the species) have not been realised since its introduction in 2000. Comment from Tim Riding (Senior Advisor, Marine Surveillance and Incursion Investigation, New Zealand—Jan 2017): 'There is very little work quantifying the impacts of *Charybdis*. There is a bit of correlative evidence from catch data from the port surveillance programme—declines in catch rates of the native paddlecrab *Ovalipes catharus*, which has a small commercial, recreational and customary fishery associated with increases in *C. japonica*. However, it is not clear whether or not this because of *C. japonica* is excluding the native from entering the traps, or is in fact a real trend where *C. japonica* has displaced *O. catharus*.'
		The species is likely to lead to the extinction or significant decline of a nationally protected or endangered species or community.	False	No known evidence.
		The species negatively impacts ecologically valuable marine species.	False	No known evidence.
		The species negatively impacts places of nationally importance (relevant to the national identity).	False	No known evidence.
		The species negatively impacts ecologically valuable places.	False	No known evidence.
2B	Social impacts	The species negatively impacts infrastructure used by a significant proportion of people.	False	No known evidence.
		The species negatively impacts amenity of resources used by a significant proportion of people over and extensive area.	False	No known evidence.

Category code	Impact category	Criterion	True, false or unknown	Justification
		The species negatively impacts cultural assets valued by particular sections of the community.	False	No known evidence.
2C	Business impacts	The species negatively impacts the profitability of recreational or commercial fisheries (including aquaculture).	Unknown	No documented impacts, only speculation about potential impacts.
		The species negatively impacts the profitability of any other industry directly reliant on utilisation of and/or access to the marine environment.	Unknown	No known evidence.
		The species negatively impacts product acceptability in international markets and/or state/territory access to domestic markets.	Unknown	No known evidence.
		The species negatively impacts international and/or domestic shipping due to increased costs of meeting required biosecurity standards.	Unknown	No known evidence.
2D	Human health impacts	The species is likely to cause illness and/or physical injury to people resulting in deaths, permanent disabilities and/or substantial long-term health costs to the community.	Unknown	No known evidence.
3	Response	The species progress to Step 3, and recommendation for the APMPL.	False	The impacts of *C. japonica* are not yet clear or significant.

Chthamalus proteus

Phylum: Arthropoda

Common names: Caribbean barnacle, Atlantic barnacle

Status: Exotic

Assessed by John Lewis; reviewed by Jessica Evans

Table G25 Step 1 assessment for *Chthamalus proteus*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Chthamalus proteus* is a marine species—it can live in salinity range of 22 ppt to 35 ppt, and it can tolerate short periods of freshwater and tidal exposure. The observed temperature range in which it survives is 16 °C to 38 °C. It can survive in clear and turbid waters and is highly tolerant of disturbed environments (polluted harbours and lagoons) (Zabin et al. 2007).
1B	The species is not native.	True	The species is not native to Australia. *C. proteus* is native to the Caribbean Atlantic (southern Florida to Parana State, Brazil); and has been introduced to the Hawaiian Islands, Midway Island, Guam and French Polynesia (CABI 2017c; Zardus & Hadfield 2005)
1C	The species is not on the EPBC Act live import list.	True	*C. proteus* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	The genus *Chthamalus* comprises approximately 20 species that are difficult to separate morphologically and often needs molecular methods to separate the species (Dando et al. 1979; Hedgecock 1979; Dando 1987; Wares 2001; Southward & Newman 2003; as cited in Zardus & Hadfield 2005). The difficulty in identifying the species in the field has been described, 'As *Chthamalus* species are often hard to distinguish in the field, it is entirely possible that *C. proteus* would go undetected for a period of time on the west coast of the USA and Mexico', and has been summarised as 'Difficult to identify/detect in the field' (CABI 2017c). This would be similarly likely to occur in Australia, as the rocky shore upper-intertidal habitat is shared by the similar sized (less than 10 mm across) native *C. antennatus* in southern Australian (Queensland to Western Australia), and *C. malayensis* on the northern coastline.
1E	The species could feasibly be controlled in the environment.	False	With a short time to sexual maturity and a relatively short larval life span (Zabin et al. 2007), *C. proteus* is capable of rapid spread, and has been summarised as 'difficult/costly to control' (CABI 2017c). Given the difficulty of identifying the species, spread is probable by the time of detection.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	Biofouling and or movements of small domestic vessels would need to be managed to prevent spread of *C. proteus*.

Criterion code	Criterion	True or false	Justification
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*C. proteus* is not known to be present in Australia
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	*C. proteus* is considered most likely to have been introduced to the Pacific Islands—and spread between them—as biofouling on vessels (Zabin et al. 2007).
1I	The species has the potential to become established in Australian waters	True	*C. proteus* is a substrate generalist. It can live in salinity range of 22 ppt to 35 ppt, and can tolerate short periods of freshwater and tidal exposure. The observed temperature range in which it survives is 16 °C to 38 °C. It can survive in clear and turbid waters and highly tolerant of disturbed environments (polluted harbours and lagoons) (Zabin et al. 2007).
2	This species progresses to Step 2 (all criteria are true).	False	*C. proteus* does not pass Step 1: it would be difficult to accurately identify in the field (1D); it could not feasibly be controlled in the environment (1E).

Eriocheir sinensis

Phylum: Arthropoda

Common name: Chinese mitten crab

Status: Exotic

Assessed by Tim Glasby; reviewed by Jessica Evans

Table G26 Step 1 assessment for *Eriocheir sinensis*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	The genus is catadromous, only venturing into marine waters to mate (Naser et al. 2012). Salinity tolerance is 0 ppt to 35 ppt (Glasby & Lobb 2008; NIMPIS 2017g).
1B	The species is not native.	True	*Eriocheir sinensis* is native to the Far East, from China (approximately 26°N) northwards to the Korean Peninsula (approximately 40°N) (Clark et al. 1998). *E. sinensis* has successfully invaded mainly temperate regions in central and northern Europe and North America (Naser et al. 2012). There is no record for *E. sinensis* listed in Australia (Naser et al. 2012).
1C	The species is not on the EPBC Act live import list.	True	*E. sinensis* is not listed on the EPBC Act live import list.
1D	The species is:	True	Molecular studies have suggested that mitten crabs (previously thought to be just four species in the one genus) actually comprise three genera and six species (*E. japonica, E. sinensis, E. hepuensis* and *E. ogasawaraensis, Neoerio-cheir leptognathus* and *Platyeriocheir Formosa*). However, hybridisation

Criterion code	Criterion	True or false	Justification
	• identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.		between *E. sinensis* and *E. hepuensis* and between *E. japonica* and *E. sinensis* has been reported in aquaculture experiments (Naser et al. 2012). Although species identification may be problematic, there are no known Australian native species in this genus (Naser 2012); therefore, identification to genus would be feasible. It is a moderate-sized crab—max carapace width approximately 80 mm.
1E	The species could feasibly be controlled in the environment.	True	Control of *E. sinensis* is difficult and eradication programmes are unsuccessful once the crab has established self-sustaining populations (Gollasch 2006 as cited in Gollasch 2011). The 'catch as many as you can' strategy has shown limited success (Gollasch 2006). Despite the best efforts, no effective management approach has been developed and all eradication efforts have shown limited efficiency (Gollasch 2006 as cited in Gollasch 2011). If controlled early, potential options could include physical controls (traps, trawls and barriers), commercial harvest and exclusion devices.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	Shipping is the most likely vector (together with intentional transport) (Bently 2011). Ballast water management could theoretically limit the spread to new estuaries. Adult *E. sinensis* spawn in estuaries and many larval stages require at least 16 ppt to 17 ppt to survive (see Rudnick et al. 2005a). Later stages are apparently more tolerant of higher salinities (32 ppt; Anger 1991 as cited in ANSTF 2002) and have a plaktonic larval duration range of about 40 days depending on temperature. Thus, coastal transport would only be likely in areas where nearshore salinities are less than 32 ppt. This would probably occur only after heavy rainfall and only around the mouths of individual estuaries (except perhaps in some areas of the tropics). Optimal water temperatures for all larval stages range from 15 °C to 18 °C (Anger 1991), meaning that the species could only survive in southern regions of Australia. Overall, it seems unlikely that the species would disperse naturally among estuaries in Australia.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*E. sinensis* is listed as absent in Australia (NIMPIS 2017g).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	Hayes et al. (2005) suggest that *E. sinensis* is a medium–low priority for Australia based on invasion potential and impact potential. The species is native to Asia and ranked likely to be introduced to Botany Bay (Glasby & Lobb 2008) and Western Australia (Bridgwood & McDonald 2014) via commercial shipping (ballast).
1I	The species has the potential to become established in Australian waters	True	*E. sinensis* tolerates salinities between 0 ppt to 35 ppt (normal range salinity 15 ppt to 25 ppt) and temperature 0 to 30 °C (normal temperature range is 12 °C to 18 °C). Ideal salinity for reproduction is 16 ppt to 30 ppt (Glasby & Lobb 2008), so species could live and establish in southern parts of Australia.
2	This species progresses to Step 2 (all criteria are true).	True	*E. sinensis* meets all the criteria for Step 1.

Table G27 Step 2 assessment for *Eriocheir sinensis*

Category code	Impact category	Criterion	True, false or unknown	Justification
2-0	Impact intensity (prerequisite)	The species is likely to reach high densities and maintain its invasiveness over time.	True	In areas where *E. sinensis* has become established, eradication programs have been unsuccessful due to the high reproductive rate and abundance and high tolerance of a wide range of abiotic factors. Range extensions are likely occur with drift of larvae or following the active migration of juvenile and adult species via rivers and canals (Arndt 1931; Boettger 1933; Luther 1934; Pienimäki & Leppäkoski 2004). The species has a wide range of impacts on the environment and human health (Glasby & Lobb 2008).
2A	Environmental impacts	The species negatively impacts the physical environment, biodiversity, ecological structure or function, or ecosystem services.	True	Evidence for ecological impacts relates primarily to freshwater (and perhaps brackish) environments, such as the impacts of large numbers of burrowing crabs on stream banks (Rudnick et al. 2005). There is some evidence for the species competing with native estuarine crabs (including *Carcinus maenas,* which is introduced in Australia) and freshwater crayfish. Effects on prey items (such as freshwater shrimp) have been hypothesised based on feeding trials (see Dittel & Epifanio 2009).
		The species is likely to lead to the extinction or significant decline of a nationally protected or endangered species or community.	False	No known evidence.
		The species negatively impacts ecologically valuable marine species.	False	No known evidence.
		The species negatively impacts places of nationally importance (relevant to the national identity).	False	No known evidence.
		The species negatively impacts ecologically valuable places.	False	No known evidence.
2B	Social impacts	The species negatively impacts infrastructure used by a significant proportion of people.	False	No known evidence.
		The species negatively impacts amenity of resources used by a significant proportion of people over and extensive area.	False	No known evidence.
		The species negatively impacts cultural assets valued by particular sections of the community.	False	No known evidence.

Category code	Impact category	Criterion	True, false or unknown	Justification
2C	Business impacts	The species negatively impacts the profitability of recreational or commercial fisheries (including aquaculture).	Unknown	*E. sinensis* seems most likely to affect freshwater industries due to, for example, entrainment resulting in equipment being clogged (see Dittel & Epifanio 2009).
		The species negatively impacts the profitability of any other industry directly reliant on utilisation of and/or access to the marine environment.	Unknown	No known evidence.
		The species negatively impacts product acceptability in international markets and/or state/territory access to domestic markets.	Unknown	No known evidence.
		The species negatively impacts international and/or domestic shipping due to increased costs of meeting required biosecurity standards.	Unknown	No known evidence.
2D	Human health impacts	The species is likely to cause illness and/or physical injury to people resulting in deaths, permanent disabilities and/or substantial long-term health costs to the community.	Unknown	*E. sinensis* is a secondary host for lung fluke, but the crab must be eaten raw for infection.
3	Response	The species progress to Step 3, and recommendation for the APMPL.	True	*E. sinensis* has potential for significant negative impacts on the environment (2A).

Table G28 Step 3 assessment for *Eriocheir sinensis*

Criterion code	Criterion	True or false	Justification
3A	There is a national control plan for the species. (If false, provide details of known control options.)	True	There are national control plans overseas.
3B	There are molecular tools for identifying the species.	True	Molecular tools have been used to study *Eriocheir* spp. and related genera (Naser et al. 2012).
3C	The potential distribution of the species has been modelled.	True	The potential distribution of *Eriocheir* spp. has been modelled using the invasive marine species mapping program (Richmond et al. 2010).

Gmelinoides fasciatus

Phylum: Arthropoda

Common name: Baikalian amphipod

Status: Exotic

Assessed by Alex Chalupa; reviewed by Jessica Evans

Table G29 Step 1 assessment for *Gmelinoides fasciatus*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	False	*Gmelinoides fasciatus* is a freshwater species; although a study by Berezina et al. (2001) suggests they can reproduce in salinities less than 2 ppt, and can survive as adults in salinities less than 7 ppt in experimental conditions. Therefore, this species should be referred to the freshwater group for assessment.
1B	The species is not native.	True	There are no records of *G. fasciatus* in Australia. The species is native to Lake Baikal, the Angara River and the Yensei River and it has been introduced into several lakes in the Gulf of Finland basin of the Baltic Sea (Berenzina et al. 2001).
1C	The species is not on the EPBC Act live import list.	True	*G. fasciatus* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	*G. fasciatus* is very similar to other amphipods and would be difficult to distinguish from other similar species.
1E	The species could feasibly be controlled in the environment.	False	*G. fasciatus* would be difficult to control a freshwater system due to size and difficulty to isolate target species (Alex Chalupa, pers. comm.).
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	The only way *G. fasciatus* could get here is by accidental or illegal import. Movement of freshwater and aquarium trade species is controlled by border screening to ensure amphipods are not permitted into Australia.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*G. fasciatus* is not known in Australia.
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	False	The only way *G. fasciatus* could get here is by accidental or illegal import. Movement of freshwater and aquarium trade species is controlled by border screening to ensure amphipods are not permitted into Australia.

Criterion code	Criterion	True or false	Justification
1I	The species has the potential to become established in Australian waters	False	Unlikely in marine waters given salinity tolerance. Refer species to freshwater group for assessment.
2	This species progresses to Step 2 (all criteria are true).	False	*G. fasciatus* does not pass Step 1: it is a (mainly) freshwater species (1A) and as such has been referred to the freshwater task group. In addition, it would be difficult to accurately identify in the field (1D); it could not feasibly be controlled in the environment (1E); and is unlikely to establish in marine waters in Australia (1I).

Hemigrapsus sanguineus

Phylum: Arthropoda

Common names: Japanese shore crab, Asian shore crab

Status: Exotic

Assessed by Tim Glasby; reviewed by Jessica Evans

Table G30 Step 1 assessment for *Hemigrapsus sanguineus*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Hemigrapsus sanguineus* inhabits coastal and estuarine environments (Epifanio 2013). NIMPIS (2017h) suggests that the adult salinity range is from 5 ppt to 53 ppt.
1B	The species is not native.	True	No data recorded for *H. sanguineus* being present in Australia (NIMPIS 2017h). The species is native to China, Hong Kong, Taiwan, Korea, Russia, and Japan. *H. sanguineus* has been introduced to the United States and in Europe from Northern France, Belgium, Netherlands, Germany and Denmark (Rømø Island) (CABI, 2017e; Dauvin et al. 2009; Epifano 2013).
1C	The species is not on the EPBC Act live import list.	True	*H. sanguineus* Hemigrapsus sanguineus is not listed on the EPBC Live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	Rapid discrimination from natives is difficult. Although there do not seem to be any Australian natives in this genus, native grapsids such as *Cyclograpsus*, *Leptograpsus* and *Paragrapsus* will look similar in the field. Molecular markers for *H. sanguineus* are available (Poux et al. 2015). The carapace of *H. sanguineus* ranges from green through to purple, orange-brown or red. It has shaded bands on its legs and red spots on its claws. It is a relatively small, square-shelled crab with a carapace width of 35 to 40 mm. Distinguishing features include the presence of three spines on each side of the carapace (NIMPIS 2017h).
1E	The species could feasibly be controlled in the environment.	True	Adult *H. sanguineus* could feasibly be trapped. Opera house traps used in New South Wales have caught small *C. maenas* (22–30 mm carapace width) (NSW DPI unpublished; Garside et al. 2014). Traps with smaller mesh size could also be used if wanting to catch smaller crabs. Spat collectors can be used to sample

Criterion code	Criterion	True or false	Justification
			individuals settling out from the plankton (Garside et al. 2015), although this might not be a particular effective control method. Like other grapsid crabs, *H. sanguineus* larvae are released in estuaries and transported offshore before returning to the estuaries to settle (Epifanio 2013); meaning natural dispersal would be great. Planktonic larval duration is temperature dependent, but is approximately 20 days at 25 °C or longer at cooler temperatures (see Epifanio 2013). There is no literature available on a successful control method for the species, but in theory, control would not be greatly different from that for species such as *C. maenas*. If adults were transported here, then they could potentially be controlled. However, if the species started reproducing, control would be very difficult.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	In the initial stages of an incursion, *H. sanguineus* could potentially be transported on hulls of recreational or commercial vessels (Gollasch 1999), which can feasibly be managed. Natural dispersal is likely to be great, given larvae are transported offshore and return to settle in estuaries. However, the species may not be able to spread to other jurisdictions if there are no natural connections (such as if currents flow in the wrong direction or if distances between estuaries too great).
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	No data recorded for *H. sanguineus* being present in Australia (NIMPIS 2017h).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	Hayes et al. (2005) suggest that *H. sanguineus* is a medium–high priority based on invasion potential and impact potential. Hayes & Sliwa (2003) suggested that possible vectors for arrival of *H. sanguineus* to Australia are accidental introduction with ballast. The species is native to Asia and has been ranked likely to be introduced to Botany Bay (Glasby & Lobb 2008) and Western Australia (Bridgwood & McDonald 2014) via commercial shipping.
1I	The species has the potential to become established in Australian waters	True	Hayes & Sliwa (2003) have listed *H. sanguineus* on the potential 'next pest' Australia list and Hayes et al. (2005) have suggested this as a medium-high priority pest given its invasion/impact potential and that *H. sanguineus* is one of 10 most likely invaders based on environmental similarity between donor and recipient ports. *H. sanguineus* could establish in Australia given its ability to tolerate a wide range of temperatures, of between –0.8 °C to 27 °C. However, there is limited data on salinity tolerances with a narrow range of 30 ppt to 33 ppt. However, species in the same genus are shown to tolerate salinities of 0–32 ppt (*H. nudus*), 24–48 ppt (*H. edwardsii*) and 12–42 ppt (*H. crenulatus*) (O'Loughlin et al. 2006). NIMPIS (2017h) suggests a salinity tolerance of 5 to 53 ppt.
2	This species progresses to Step 2 (all criteria are true).	False	*H. sanguineus* does not pass Step 1: it would be difficult to accurately identify in the field (1D).

Hemigrapsus takanoi

Phylum: Arthropoda

Common name: Takano's shore crab

Status: Exotic

Assessed by Tim Glasby; reviewed by Jessica Evans

Table G31 Step 1 assessment for *Hemigrapsus takanoi*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Hemigrapsus takanoi* has a salinity tolerance of between 0 ppt and 40 ppt and lives in lives in rocky intertidal and muddy subtidal environments (NIMPIS 2017i).
1B	The species is not native.	True	There is no data for *H. takanoi* being present in Australia (NIMPIS 2017i). Hemigrapsus takanoi is native to the western Pacific, but has been introduced to the European Atlantic, North sea coasts and Baltic seas (Geburzi et al. 2015 and references within). The species has recently been distinguished from another invader *H. penicillatus* (Asakura & Watanabe 2005; Markert et al. 2014 as cited in CABI 2017f), and many *H. penicillatus* invasions in Europe may actually be *H. takanoi* (Gebruzi et al. 2015).
1C	The species is not on the EPBC Act live import list.	True	*H. takanoi* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	Rapid discrimination from natives is difficult. Although there do not seem to be any Australian natives in this genus, native grapsids such as *Cyclograpsus*, *Leptograpsus* and *Paragrapsus* will look similar in the field. Molecular markers for *H. sanguineus* are available (Poux et al. 2015) as well as for *H. takanoi* (Markert et al. 2014). *H. takanoi* is commonly orange-brown in colour but can also be green or maroon. It is a very small species, max carapace width approximately 30 mm, making identification in the field even more difficult. It can be distinguished by the brown/yellow setal patch, found at the base of the pincers on the males' claws (NSW DPI n.d. as cited in NIMPIS 2017i). On each side of the square carapace, there are three lateral spines (Salem Sound Coastwatch as cited in NIMPIS 2017i). There are also light and dark bands on the legs and dark spots on the chelae (Salem Sound Coastwatch as cited in NIMPIS 2017i).
1E	The species could feasibly be controlled in the environment.	True	There is not much literature on *H. takanoi*, but reproduction is very likely to be similar to *H. sanguineus* (larvae are released in estuaries and transported offshore before returning to estuaries to settle) (Epifanio 2013), meaning natural dispersal would be great. Planktonic larval duration is temperature dependent, but is approximately 20 days at 25 °C or longer at cooler temperatures (Epifanio 2013). In established populations, control of dispersal would likely be impossible. However, it may not be able to

Criterion code	Criterion	True or false	Justification
			spread to other jurisdictions if there are no natural connections (such as if currents are in the wrong direction or distances between estuaries are too great). Control options seem limited apart from prevention of introduction by management of ballast water and fouling—given the rapid spread in Europe, aided by natural dispersal of pelagic larvae across a wide range of salinities/temperatures, if there were to be an incursion, it is unlikely that it could be controlled or contained. However, it has not been determined whether the rapid spread throughout Europe has been aided by the larvae–ballast relationship or whether natural dispersal has been a major contributor (more studies are needed). In the Wadden Sea, it was suggested that a change from using hard structures for sea defences to soft defences could limit further spread of this species (Landschoff et al. 2013 as cited in CABI 2017f).
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	In the initial stages of an incursion *H. takanoi* could potentially be transported on hulls of recreational or commercial vessels (Gollash 1999), which can feasibly be managed. Natural dispersal is likely to be great, given larvae are transported offshore and return to settle in estuaries. However, it may not be able to spread to other jurisdictions if there are no natural connections (such as if currents flow in the wrong direction or if distances between estuaries too great).
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	There is no data for *H. takanoi* being present in Australia (NIMPIS 2017i).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	*H. takanoi* is native to Western Pacific (Asia) and ranked likely to be introduced to Botany Bay (Glasby & Lobb 2008) via commercial shipping. Vectors in previous introductions have included hull fouling, ballast water and oyster shipments (CABI 2017f).
1I	The species has the potential to become established in Australian waters	True	Because of the wide range of tolerances—it lives in bays in estuaries in its native range where salinity can fluctuate between 7 ppt and 35 ppt (NIMPIS 2017i suggests 0 ppt to 40 ppt) and temperature between 12.5 °C to 20 °C (Shinji et al. 2009)— *H. takanoi* is likely able to establish in Australia.
2	This species progresses to Step 2 (all criteria are true).	False	*H. takanoi* does not pass Step 1. It would be difficult to accurately identify in the field (1D).

Hesperibalanus fallax

Phylum: Arthropoda

Common name: Shell barnacle

Status: Exotic

Assessed by Richard Willan; reviewed by Sandra Parsons

Table G32 Step 1 assessment for *Hesperibalanus fallax*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Hesperibalanus fallax* is marine for its entire life cycle. It is an epibiotic species, typically found in shallow seas (Hosie 2008).
1B	The species is not native.	True	*H. fallax* is not native to Australia, or established. It is considered native to tropical regions of the Atlantic coast of Africa, and to have extended its range north through Portugal and France to Belgium and the Netherlands (Hosie 2008).
1C	The species is not on the EPBC Act live import list.	True	*H. fallax* is not on this list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	*H. fallax* has been characterised morphologically by Hosie (2008). The genus Solidobalanus, in which it is often placed, is incorrect (Southward 2013). It could easily be confused with other native acorn barnacles.
1E	The species could feasibly be controlled in the environment.	False	*H. fallax* is found in the upper sublittoral to around 200 m. It is typically epibiotic on a wide range of organisms including other crustaceans, hydroids, algae and molluscs (Southward et al. 2004). It has also been recorded from man-made objects such as plastics and lobster pots (Southward et al. 2004; Hosie 2008). Therefore, because of its habit of attaching to floating objects and depth distribution, it could not be controlled in the environment (Richard Willan [APMPL task group] pers. comm.).
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	Due to the species' habit of attaching to floating objects and other organisms, controlling the spread of *H. fallax* via natural dispersal would be difficult (Richard Willan [APMPL task group] pers. comm.).
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*H. fallax* is presently not in Australian waters. There are no records of the species on NIMPIS (2009) or Atlas of Living Australia (ALA 2017a).

Criterion code	Criterion	True or false	Justification
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	A study by Gruet et al. (2014) suggests that *H. fallax* arrived in Europe by either fouling or ballast from Western Africa. However, existing regulations for aquacultural imports and ballast water management should ensure it does not reach Australia.
1I	The species has the potential to become established in Australian waters	True	*H. fallax* tolerates a wide range of temperatures.
2	This species progresses to Step 2 (all criteria are true).	False	*H. fallax* does not pass Step 1: it can be confused with other native barnacles in the field (1D); it cannot be controlled in the environment (1E); and vectors and pathways cannot feasibly be managed (1F).

Pachygrapsus fakaravensis

Phylum: Arthropoda

Common name: Polynesian grapsid crab

Status: Exotic

Assessed by Alicia McArdle; reviewed by Jessica Evans

Table G33 Step 1 assessment for *Pachygrapsus fakaravensis*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Pachygrapsus fakaravensis* is an exclusively marine intertidal species (Eldridge & Smith 2001).
1B	The species is not native.	True	*P. fakaravensis* is exotic to Australia. It is native to French Polynesia, and has been introduced to Japan, Taiwan (CRUSTA database 2012), Hawaii (Eldridge & Smith 2001) and Reunion Island (Poupin & Juncker 2010).
1C	The species is not on the EPBC Act live import list.	True	*P. fakaravensis* is not on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	Thirteen species in the genus *Pachygrapsus* (including *P. fakaravensis*) have been described by Poupin et al. (2005). A similar species is found in Hawaii, *P. plicatus*. The species can be separated by ‘the shape of the lateral carapace margins (subparallel in *P. fakaravensis*, posteriorly convergent in *P. plicatus*), the presence of setae on the longitudinal striae of the outer face of the chelae of *P. fakaravensis*, and by the abdominal tergites having short striae in *P. fakaravensis* but being smooth in *P. plicatus*.’ (Poupin et al. 2005). *P. fakaravensis* could not be distinguished from Australian native crabs in the field.

Criterion code	Criterion	True or false	Justification
1E	The species could feasibly be controlled in the environment.	True	Unknown, it appears that no one has tried to control this crab.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	*P. fakaravensis* is believed to have been spread as larvae in ballast water (Eldridge & Smith 2001), and this could feasibly be managed. Natural dispersal via the planktonic larval stage of *P. fakaravensis* means dispersal to other regions could potentially be great (Eldridge & Smith 2001).
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*P. fakaravensis* is not present in Australia.
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	*P. fakaravensis* could potentially be transported to Australia via an anthropomorphic vector. However, the likelihood is low—as determined in the Species Biofouling Risk Assessment (Hewitt et al. 2011).
1I	The species has the potential to become established in Australian waters	True	The temperature tolerance of *P. fakaravensis* has been reported between –2.9 °C and 32.1 °C (Hewitt et al. 2011), therefore, based on temperature tolerance alone, it is likely that it could establish in Australia.
2	This species progresses to Step 2 (all criteria are true).	False	*P. fakaravensis* does not pass Step 1: it would be difficult to accurately identify in the field (1D).

Petrolisthes elongates

Phylum: Arthropoda

Common names: New Zealand porcelain crab, New Zealand half-shell crab

Status: Established

Assessed by Jeff Wright; reviewed by the task group

Table G34 Step 1 assessment for *Petrolisthes elongates*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Petrolisthes elongates* is described in surveys on northern Tasmanian coast (Gribben et al. 2013, 2015)
1B	The species is not native.	True	Most likely date of introduction of *P. elongates* is early 1990s (Dartnall 1969; King 1997)

Criterion code	Criterion	True or false	Justification
1C	The species is not on the EPBC Act live import list.	True	*P. elongates* is not on the EPBC import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	*P. elongates* is very distinct from native porcelain crabs.
1E	The species could feasibly be controlled in the environment.	True	*P. elongates* could be feasibly controlled in a localised situation such as a small bay or harbour.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	Likely vectors would be hitchhiking on vessels, fishing gear or live rock
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	True	*P. elongates* is the most abundant intertidal species in boulder field of northern and south-eastern Tasmania. There are many similar habitats in other jurisdictions.
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	*P. elongates* densities in northern/south-eastern Tasmania reach greater than 1,800/m^2 (Gribben et al. 2013)
1L	The species is not widely cultivated in Australia.	True	*P. elongates* is not widely cultivated in Australia.
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	True	So far, *P. elongates* is established only in Tasmania and Victoria.
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	Short-distance dispersal (tens of kilometres) of *P. elongates* via larvae is likely, but longer distance (hundreds to thousands of kilometres) is due to anthropogenic vectors.
2	This species progresses to Step 2 (all criteria are true).	True	*P. elongates* meets all criteria for Step 1.

Table G35 Step 2 assessment for *Petrolisthes elongates*

Category code	Impact category	Criterion	True, false or unknown	Justification
2-0	Impact intensity (prerequisite)	The species is likely to reach high densities and maintain its invasiveness over time.	True	Densities in northern/south-eastern Tasmania reach greater than 1,800/m^2 (Gribben et al. 2013)
2A	Environmental impacts	The species negatively impacts the physical environment, biodiversity, ecological structure or function, or ecosystem services.	Unknown	The scientific evidence is currently limited to descriptive studies, which indicate high densities of *Petrolisthes elongatus* are correlated with differences in native species community structure (Gribben et al. 2015). No experimental studies have been done. As a filter feeder, its impacts may more difficult to detect than a large predator in experimental studies but the consistently high densities it reaches on invaded shore warrants further attention.
		The species is likely to lead to the extinction or significant decline of a nationally protected or endangered species or community.	Unknown	No known evidence.
		The species negatively impacts ecologically valuable marine species.	Unknown	No known evidence.
		The species negatively impacts places of nationally importance (relevant to the national identity).	Unknown	No known evidence.
		The species negatively impacts ecologically valuable places.	Unknown	No known evidence.
2B	Social impacts	The species negatively impacts infrastructure used by a significant proportion of people.	Unknown	No known evidence.
		The species negatively impacts amenity of resources used by a significant proportion of people over and extensive area.	Unknown	No known evidence.
		The species negatively impacts cultural assets valued by particular sections of the community.	Unknown	No known evidence.
2C	Business impacts	The species negatively impacts the profitability of recreational or commercial fisheries (including aquaculture).	Unknown	No known evidence.
		The species negatively impacts the profitability of any other industry directly reliant on	Unknown	No known evidence.

Category code	Impact category	Criterion	True, false or unknown	Justification
		utilisation of and/or access to the marine environment.		
		The species negatively impacts product acceptability in international markets and/or state/territory access to domestic markets.	Unknown	No known evidence.
		The species negatively impacts international and/or domestic shipping due to increased costs of meeting required biosecurity standards.	Unknown	No known evidence.
2D	Human health impacts	The species is likely to cause illness and/or physical injury to people resulting in deaths, permanent disabilities and/or substantial long-term health costs to the community.	Unknown	No known evidence.
3	Response	The species progress to Step 3, and recommendation for the APMPL.	False	Insufficient information about the impacts of *P. elongates.*

Pyromaia tuberculata

Phylum: Arthropoda

Common name: American spider crabl

Status: Established

Assessed by Michelle Besley; reviewed by Jessica Evans

Table G36 Step 1 assessment for *Pyromaia tuberculate*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Pyromaia tuberculata* is a sub-tidal species and lives in reef habitat types (NIMPIS 2017n)
1B	The species is not native.	True	*P. tuberculata* is not native to Australia. It was introduced to Australia, New Zealand, Brazil, Japan and Korea from the Pacific coast of North America (NIMPIS 2017n). It was first found in Western Australia in 1978 (Morgan 1990 as cited in Ahyong 2005).The species has since been reported from Port Phillip Bay, Victoria, where it has been present since at least 1990 (Poore & Storey 1999 as cited in Ahyong 2005).

Criterion code	Criterion	True or false	Justification
1C	The species is not on the EPBC Act live import list.	True	*P. tuberculata* is not on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	The species can be identified with a high degree of taxonomic certainty and in the field, noting that individuals are very small. Adult *P. tuberculata* are distinguishable from native Australian Majid species by a triangular convex carapace with granulate and tuberculate surface, simple pointed rostrum unique (all native Australian species have bifid rostrums), legs decreasing in length from 1st to 4th and small size (Poore & Storey 1999 as cited in Ahyong 2005). *P. tuberculata* have two zoeal stages. Zoea lack rostral and lateral carapace spines, characteristic distal portion of dorsal spine sharply curved, little evidence of antenna 2 endopod in zoea 1 and long forward directed and acicular abdominal protuberances on abdominal segment 2 (NIMPIS 2017n).
1E	The species could feasibly be controlled in the environment.	False	Because *P. tuberculata* can go to extreme depths of 430 m (NIMPIS 2017n), control would be difficult if occupying these areas. As this species is small (20 mm) (NIMPIS 2017n), trapping is an unlikely control method.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	*P. tuberculata* is thought to be introduced by ballast water, which could be further managed to limit spread.
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	False	There are no known impacts of *P. tuberculata* within Australian waters or other areas (NIMPIS 2017n). Therefore, it is unlikely that there is a national interest in containing the species and improving its management. However, Ahyong (2005) suggested that further study is required to adequately assess their impacts and modes of dispersal.
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	False	*P. tuberculata* is established in Australia; there are no known eradication attempts. This species can go to extreme depths of 430 m (NIMPIS 2017n) impacting feasibility for eradication.
1L	The species is not widely cultivated in Australia.	True	*P. tuberculata* is not widely cultivated, it is only a very small species, growing up to 22 mm.
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	True	*P. tuberculata* is found in New South Wales, Western Australia and South Australia, and could establish in Tasmania and Queensland given the species environmental tolerances. Reproductive temperature range is 8 °C to 26 °C and it can be found in very deep water (maximum depth of 430 m) (NIMPIS 2017n).
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	The main vectors for *P. tuberculata* includes ballast water, biofouling and others (potentially aquaculture and fisheries activities) (NIMPIS 2017n). It has spread to multiple countries probably as larvae in ballast water (Poore 2004 as cited in Ahyong 2005). A population has been found in Newcastle and it is uncertain whether this is a natural expansion of the Victorian population or a separate introduction (Ahyong 2005). The larvae stages of this species are unknown (Fransozo & Negreiro-Fransozo 1970 as cited in Poore 2004).

Criterion code	Criterion	True or false	Justification
2	This species progresses to Step 2 (all criteria are true).	False	*P. tuberculata* does not pass Step 1: it cannot feasibly be controlled in the environment (1E); and there is unlikely to be national interest in containing its spread or improving its management (1J).

Rhithropanopeus harrisii

Phylum: Arthropoda

Common name: Harris' mud crab

Status: Exotic

Assessed by Alicia McArdle and Michelle Besley; reviewed by Jessica Evans

Table G37 Step 1 assessment for *Rhithropanopeus harrisii*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Rhithropanopeus harrisii* is a euryhaline species (Dowell 2011). Adult salinity range is between 0.4 ppt and 40.0 ppt. The crab is a small euryhaline decapod crab. It inhabits oligohaline to brackish marine waters (Zaitsev & Ozturk 2001; Peterson 2006; as cited in NIMPIS 2017o)
1B	The species is not native.	True	This species is not native to Australia and is not yet detected in Australian waters (NIMPIS 2017o). It is native to the Atlantic coast of America from New Brunswick to north-east Brazil. It was introduced to the British Isles (Eno et al. 1997 as cited in NIMPIS 2017o). It is found in upper estuarine areas of the north west Atlantic in fresh & brackish water (NIMPIS 2017o).
1C	The species is not on the EPBC Act live import list.	True	*R. harrisii* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	*R. harrisii* can be identified with a high degree of taxonomic certainty and should be able to be distinguished from natives in the field. The crab has five carapace teeth, the first 1 and 2 are coalesced, teeth 3–5 are dentate, with the last being the smallest. *R. harrisii* has four lateral teeth, the first two antero-lateral teeth fused with the last three dentiform. The frontal margin is transversely grooved and appears double when viewed from the front (GISD 2017l). Males are larger than females. Colours vary from greenish-brown to olive green with a white underside, its claws has white tips (Harriet 2011 as cited in GISD 2017l). *Varuna litterata* is a native species which it could be misidentified as, although it's highly unlikely as *R. harrisii* is very small, (maximum 20 mm) whereas *V. litterata* is around 55 mm.
1E	The species could feasibly be controlled in the environment.	True	Larval stages may be possible to control—an active chemical in pesticide has been used experimentally and was lethal to hatching larvae (Dowell 2011). Diflubezuron, the active chemical in the pesticide Dimilin, has been experimentally used on *R. harrisii* (McEnnulty et al. 2001 as cited in GISD 2017l). It is lethal to hatching larvae in concentrations of 7 ppb to 10 ppb. It works by inhibiting chitin synthesis and

Criterion code	Criterion	True or false	Justification
			has been found to be an effective way of controlling arthropods. However, it lacks specificity and may take several weeks to degrade in brackish water environments (Christiansen & Costlow 1980 as cited in GISD 2017l). Trapping of *R. harrisii* is likely an ineffective management option given the small size of crabs (adult carapace 10 to 20 mm in width, Milke & Kennedy 2001 as cited in GISD 2017l) and previous observations that the crabs do not enter traps, even when baited (Peterson 2006). However, since Peterson (2006) hand caught all crabs in the study, catching by hand might be an option, particularly in the initial stages of an incursion to minimise numbers. A potential biological control option is the rhizocephalan barnacle *Loxothylacus panopaei*, which parasitizes *R. harrisii* in its native range, stunting growth and preventing reproduction by parasitic castration. However, further studies are necessary to determine whether *L. panopei* is a viable candidate for biological control *R. harrisii* in its introduced range (see GISD 2017l).
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	The main dispersal vector of *R. harrisii* is through ballast water displacement (Harriet 2011), therefore vectors can feasibly be managed with preventative measures for ballast water. Dowell (2011) also mentioned that the species first arrived in Europe via animal shipments for aquaculture or through hull fouling. Policies around biofouling and movement of oyster spat for farming should prevent the spread. *R. harrisii* uses mainly vertical migration so that larvae remain in the home estuary. However, a previous study suggested that a small number may exit their home estuary (occurred in Portugal) (Goncalves et al. 2005 as cited in Peterson 2006). Because of the natural spread in Europe, Peterson (2006) suggested that this could occur through either a small number of larvae leaving the home estuary each year, or large numbers of larvae being swept out during rare interannual events under flood conditions. A study by Peterson (2006) of the range expansion of *R. harrisii* in the northeast Pacific suggested that the populations of *R. harrisii* were from a single introduction event in San Francisco bay. The spread between central California and Oregon was hypothesised to be due to a strong El Nino event producing high velocity nearshore currents. Therefore, natural dispersal of larvae could be great under certain conditions, but in the initial stages of an incursion, are unlikely to be a concern.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*R. harrisii* is not yet detected in Australian waters (NIMPIS, 2017o)
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	*R. harrisii* is one of the most widely distributed brachyuran invaders worldwide (Roche & Torchin 2007 as cited in GISD 2017l). The main dispersal vector of this species is through ballast water displacement from ships (Harriet 2011). However, mid ocean exchange of ballast water (in Canada) was ineffective for this species (Briski et al. 2012), where a live gravid female was detected in a ballast tank (Briski et al. 2012).

Criterion code	Criterion	True or false	Justification
1I	The species has the potential to become established in Australian waters	True	In the past century, *R. harrisii* has invaded over 20 countries across 45 degrees of latitude (Fowler et al. 2013). The optimum temperature range of the species is reported between 15 °C and 25 °C (Hegele-Drywa & Normant 2014), and the salinity range is between 0.4 ppt and 40 ppt (reproductive range is 2.5ppt to 40 ppt) (NIMPIS 2017o), therefore it is likely it could establish in Australia.
2	This species progresses to Step 2 (all criteria are true).	True	*R. harrisii* meets all criteria for Step 1.

Table G38 Step 2 assessment for *Rhithropanopeus harrisii*

Category code	Impact category	Criterion	True, false or unknown	Justification
2-0	Impact intensity (prerequisite)	The species is likely to reach high densities and maintain its invasiveness over time.	Unknown	*Rhithropanopeus harrisii* has a wide latitudinal and temperature range, and larval span of up to four weeks, but has exhibited low-density persistence in San Francisco Bay (Petersen 2006).
2A	Environmental impacts	The species negatively impacts the physical environment, biodiversity, ecological structure or function, or ecosystem services.	True	*Rhithropanopeus harrisii* is known to negatively affect prey species richness and diversity (Forsstrom et al. 2015) and could alter prey population size-structure (Forsstrom et al. 2015). No study has yet quantified the impacts of *R. harrisii*, but anecdotal reports in the scientific literature indicate that it can alter food webs, compete with and potentially displace native crabs, crayfish, as well as benthophagous fishes (reviewed in Roche & Torchin 2007 as cited in GISD 2017l). *R. harrisii* 'modified taxonomic composition and species abundances of meiobenthic communities on unvegetated soft bottom sediment' in the Baltic Sea (Lokko et al. 2015).
		The species is likely to lead to the extinction or significant decline of a nationally protected or endangered species or community.	Unknown	No known evidence, according to the literature and current list of endangered species.
		The species negatively impacts ecologically valuable marine species.	Unknown	There has been recent recruitment in Zostera marina meadows in the Baltic Sea. However, no documented evidence of shifts in community structure and composition at this stage. (Gagnom & Bostrom 2016).
		The species negatively impacts places of nationally importance (relevant to the national identity).	Unknown	It has the potential to invade wetlands, swamplands, kelp forests—observed at depths of 0 m to 20 m (Hegele-Drywa & Normant 2014). It has invaded the Great Lakes area in the United States.
		The species negatively impacts ecologically valuable places.	Unknown	There is limited information to assess this criterion. However, the species can have impacts and this may occur in an ecologically valuable place

Category code	Impact category	Criterion	True, false or unknown	Justification
2B	Social impacts	The species negatively impacts infrastructure used by a significant proportion of people.	True	In the Caspian Sea, where it has reached very high densities, the crab is responsible for fouling water intake pipes. In Texas, the crab has become very abundant in (almost) freshwater reservoirs, and it is reported to foul PVC intakes in lakeside homes and clog the cooling system of a nuclear power plant in Glenrose (Keith 2006 as cited in GISD 2017l).
		The species negatively impacts amenity of resources used by a significant proportion of people over and extensive area.	False	No known evidence.
		The species negatively impacts cultural assets valued by particular sections of the community.	False	No known evidence.
2C	Business impacts	The species negatively impacts the profitability of recreational or commercial fisheries (including aquaculture).	Unknown	This species carries a herpes-like virus that is morphologically similar to one which is lethal to the Caribbean spiny lobster (Shields & Behringer Jr 2004). It is thought that the species was spread in the United States by translocations of Atlantic oyster for aquaculture purposes. In the Caspian Sea, it causes economic losses to fishermen by spoiling fishes in gill nets (Zaitsev & Ozturk 2001 in Roche & Torchin 2007) (as cited in GISD 2017l). The species could impact prawn aquaculture being a disease carrier of white spot—*R. harrisii* has been noted as a carrier of the white spot baculovirus; a virulent disease that may affect penaeid shrimp and transmitted to other crabs species (Harriet 2011 as cited in GISD 2017l).
		The species negatively impacts the profitability of any other industry directly reliant on utilisation of and/or access to the marine environment.	Unknown	No known evidence.
		The species negatively impacts product acceptability in international markets and/or state/territory access to domestic markets.	Unknown	It could impact upon prawn aquaculture with it being a disease carrier of white spot—*R. harrisii* has been noted as a carrier of the white spot baculovirus; a virulent disease that may affect penaeid shrimp and transmitted to other crabs species (Harriet 2011 as cited in GISD 2017l).
		The species negatively impacts international and/or domestic shipping due to increased costs of meeting required biosecurity standards.	Unknown	Strong regulations are already in place for the transfer of ballast water. However, the species may increase the cost of compliance.

Category code	Impact category	Criterion	True, false or unknown	Justification
2D	Human health impacts	The species is likely to cause illness and/or physical injury to people resulting in deaths, permanent disabilities and/or substantial long-term health costs to the community.	False	No known evidence.
3	Response	The species progress to Step 3, and recommendation for the APMPL.	True	*R. harrisii* has potential for significant negative impacts on the environment (2A); on society (2B); and potentially on businesses (2C).

Table G39 Step 3 assessment for *Rhithropanopeus harrisii*

Criterion code	Criterion	True or false	Justification
3A	There is a national control plan for the species. (If false, provide details of known control options.)	False	No current control plan. This species has been identified in the species biofouling risk assessment 2011. Eradication options are listed in Roche (2008) for potential eradication in the Panama Canal.
3B	There are molecular tools for identifying the species.	True	DNA sequencing has occurred for four populations in the United States (Boyle et al. 2010), molecular studies in San Francisco Bay and surrounds (Petersen 2006), across the American and European populations (Projecto-Garcia et al. 2010).
3C	The potential distribution of the species has been modelled.	False	Not for Australia. However, it has been completed for the Panama Canal area (Roche 2008).

Bryozoa

Watersipora arcuate

Phylum: Bryozoa

Common name: Lace coral

Status: Established

Assessed by Tim Glasby; reviewed by Sandra Parsons

Table G40 Step 1 assessment for *Watersipora arcuate*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Watersipora arcuata* is a marine species. Fofonoff et al. (2003) listed the species inhabiting polyhaline (18–30 ppt) and euhaline (30–40 ppt) environments.
1B	The species is not native.	True	*W. arcuata* is a cosmopolitan fouling species, present in Australia and the United States (Mackie et al. 2006; Mackie et al. 2012). It is in all Australian states except perhaps Tasmania (Keough & Ross 1999) and throughout New Zealand (Gordon & Mawatari 1992). It has been present in Australia since at least the 1940s (Allen & Ferguson Wood 1950) when it was very abundant in New South Wales. Allen (1953) inferred that the species first arrived in Australia (on ships) sometime between 1890 and 1940 and a molecular study by Mackie et al. (2006) suggested that there are likely to have been multiple introductions in many locations.
1C	The species is not on the EPBC Act live import list.	True	*W. arcuata* is not on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	*W. arcuata* is difficult to identify in the field, but the genus can be recognised due to its colour and growth form. Very young (small) colonies would be extremely difficult to see in the field. There are only two species in the genus present in Australia and both are introduced (*W. subtorquata* and *W. arcuata*) and widespread.
1E	The species could feasibly be controlled in the environment.	False	*W. arcuata* is recorded from all states where it is likely to occur. Therefore control methods for 'a new incursion in a new jurisdiction' (as requested in the criterion explanatory information; Table D1is not applicable. *W. arcuata* fouls hulls, rocks, pontoons and pilings. The species is similar to *W. subtorquata*, for which prevention is the only control method available (GISD 2017n). Because the species grows amongst algae and large invertebrates (and can be obscured by them, or grow on them), finding colonies in the field can be very difficult. Settlement panels are normally used to sample them, but these are not useful for finding the species on natural or artificial substrata in the field. If the species is found on pilings in an early stage of

Criterion code	Criterion	True or false	Justification
			invasion, physical control may be possible, such as wrapping. However, it would be impossible to control on a large scale. The species would be very difficult to control on rocks.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	*W. arcuata* is a cosmopolitan fouling species. Mackie et al. (2006) summarise the factors contributing to the species spread on ship hulls and in ballast water. However, hull fouling may be the primary mode of introduction as the species has a short larval stage. The lecithotrophic larvae—which attach and metamorphose within one or two days following release from a colony—colonise a wide variety of artificial structures, including hulls. It is noted for its ability to settle on surfaces with copper-based antifouling paints and to survive on fast moving ships (Fofonoff et al. 2003).
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	False	*W. arcuata* is a cosmopolitan fouling species, present in most harbours throughout the world (Mackie et al. 2006) and in all Australian states except perhaps Tasmania (Keough & Ross 1999) and throughout New Zealand (Gordon & Mawatari 1992). It has been present in Australia since at least the 1940s (Allen & Ferguson Wood 1950) when it was very abundant in New South Wales. Allen (1953) inferred that the species first arrived in Australia (on ships) sometime between 1890 and 1940 and a molecular study by Mackie et al. (2006) suggested that there are likely to have been multiple introductions in many locations.
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	*W. arcuata* is a cosmopolitan fouling species.
1L	The species is not widely cultivated in Australia.	True	*W. arcuata* is not a cultivated species.
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	False	*W. arcuata* is present in all Australian states except perhaps Tasmania (Keough & Ross 1999). It has been found on the hulls of vessels in Bell Bay, Tasmania (Coutts 1999 as cited in Aquenal 2001), but there has been insufficient sampling to determine whether the species is established in Tasmania. Gordon & Mawatari (1992) suggested that the distribution of *W. arcuata* might be limited in southern New Zealand by temperature—where only dead colonies are ever found in winter south of Wellington (p. 30). Thus, it is possible that Tasmania is right on the limit of the species' temperature range.
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	Larvae of Bryozoans with lecithotrophic larvae typically do not spread more than a few hundred metres (Thorson 1950; Keough & Chernoff 1987). Mackie et al. (2006) summarise the factors contributing to spread include on ship hulls and in ballast water. However, hull fouling may be the primary mode of introduction as the species has a short larval stage.
2	This species progresses to Step 2 (all criteria are true).	False	*W. arcuata* does not pass Step 1: it is difficult to accurately identify in the field (1D); it cannot feasibly be controlled in the environment (1E); pathways and vectors cannot feasibly be managed (1F); and it is already present in all jurisdictions where it is likely to occur (1M).

Chordata

Didemnum perlucidum

Phylum: Chordata

Common name: White sea squirt

Status: Established

Assessed by Tim Glasby; reviewed by Sandra Parsons

Table G41 Step 1 assessment for *Didemnum perlucidum*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Didemnum perlucidum* is not freshwater. The salinity threshold for the species has not been established. However, colonies were found to die off in Western Australia in the Swan River estuary with low salinities due to the freshwater runoff (Simpson et al. 2016).
1B	The species is not native.	True	*D. perlucidum* is not native to Australia. It was first recorded in Australia in April 2010 in the Swan River, Perth, Western Australia (Smale & Childs 2012), and in Eden, New South Wales (NSW DPI, unpublished data). The species is currently established in Western Australia and the Northern Territory (Dias et al. 2016). The species is described as a cryptogenic species. The first described samples were from Guadeloupe in the Caribbean, where it was not clear whether it was introduced to the region, or was a minor member of the fauna (Lambert 2002). Indeed, the native range of the species is unknown. It is also described in Brazil and the Indo-West Pacific (Lambert 2002).
1C	The species is not on the EPBC Act live import list.	True	*D. perlucidum* is not on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	*D. perlucidum* was described by F. Monniot (1983) (as cited in Lambert 2002). Molecular markers are available (rapid 24-hour PCR test; Simpson et al. 2016). However, the species is extremely difficult to identify in the field, especially in southeast Australia where there are many very similar natives. However, it was possible to identify the species with reasonable accuracy in the field in Western Australia (Bridgwood et al. 2014).
1E	The species could feasibly be controlled in the environment.	True	In Australia, *D. perlucidum* has mainly been found on artificial structures from ports, harbours and marinas (Dias et al. 2016). It could theoretically be controlled in the environment (Muñoz & McDonald 2014) in the early stages of invasion, when the species is restricted to artificial structures.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	Like any fouling species, there is some hope of managing commercial vectors, but recreational vessels will be very difficult to manage.

Criterion code	Criterion	True or false	Justification
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	False	At this stage, more details on potential impacts on aquaculture in the Northern Territory and Western Australia (none known in New South Wales) are required, but it seems that current impacts on aquaculture are not great (Bridgwood et al. 2014). It seems *D. perlucidum* is on pearl farms in Western Australia, yet it is treated the same as any fouling species as and such does not have impacts over and above those of other species (Murray Barton, pers. comm.). Like any colonial fouling species, it can cover large areas of artificial structures, but it is unlikely this would be sufficient to warrant a national response.
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	*D. perlucidum* is found mainly Western Australia and the Northern Territory. Colonies have been detected in New South Wales (Twofold Bay), but few estuaries have been surveyed.
1L	The species is not widely cultivated in Australia.	True	*D. perlucidum* is not a cultivated species.
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	True	*D. perlucidum* is not known from Victoria, South Australia or Tasmania, but this is where there are many very similar looking native congeners.
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	Natural dispersal of didemnids is thought to occur over scales of tens to hundreds of metres. *D. vexillum* in New Zealand likely to be able to spread hundreds of meters naturally, maybe up to a kilometre (Fletcher et al. 2013), but these distances suggest that natural dispersal among estuaries in Australia is unlikely. Indeed the strong association of *D. perlucidum* with harbours, marinas and ports in Australia and worldwide suggest anthropogenic vectors are the most likely pathway of spread to jurisdictions (Dias et al. 2016).
2	This species progresses to Step 2 (all criteria are true).	False	*D. perlucidum* does not pass Step 1: it is difficult to accurately identify in the field (1D); and pathways and vectors cannot feasibly be managed (1F).

Didemnum vexillum

Phylum: Chordata

Common name: Carpet sea squirt

Status: Exotic

Assessed by Tim Glasby; reviewed by Sandra Parsons

Table G42 Step 1 assessment for *Didemnum vexillum*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Didemnum vexillum* was first described by Kott (2002), where it was found in estuarine waters. The species has been described as tolerating a wide range of conditions including temperature, salinity and water quality (see Lambert 2002; Lambert 2005a in Herboug et al. 2009).
1B	The species is not native.	True	*D. vexillum* is not native to Australia. There are no records of the species in Atlas of Living Australia (ALA 2017c) or NIMPIS (2017f). Molecular records indicate that the species native range is Japan (Stefanik et al. 2012).
1C	The species is not on the EPBC Act live import list.	True	*D. vexillum* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	Molecular markers for *D. vexillum* are available—rapid (24-hour) PCR detection (Simpson et al. 2016). *D. vexillum* would probably not be possible to identify in the field in most jurisdictions, especially in southeast Australia where there are many very similar natives. However, large colonies can have a ‘dripping’ appearance, which might enable it to be distinguished from natives in some situations. It might be difficult to undertake accurate delimitation surveys in estuaries where there are many similar native species, but this is possible (as done in New South Wales and Western Australia for *Didemnum* incursions). Furthermore, in the early stages of invasion, the species would very likely be restricted to artificial structures (Forrest et al. 2013), in which case, control measures could be used indiscriminately.
1E	The species could feasibly be controlled in the environment.	True	Control of *D. vexillum* incursions is theoretically possible (Coutts 2006; Pannell & Coutts 2007; Denny 2008; Piola et al. 2010; Switzer et al. 2011; Muñoz & McDonald 2014), but effective only at early stages of invasion (when species is restricted to artificial structures). See also Gittenberger (2010) who list a variety of control methods, but concludes that once the population is large, control is not possible.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	Like any fouling species, there is some hope of managing commercial vectors, but recreational vessels will be very difficult to manage. Other vectors are aquaculture infrastructure (controllable; various sources including Forrest et al. 2007), and non-trading vessels such as barges (very difficult to control). Given that the species is not yet in Australia, if it were to be found at an early stage of invasion, then control of vectors is feasible. However, once the species begins to spread, control of vectors would be very difficult.

Criterion code	Criterion	True or false	Justification
			See Gittenberger (2010)—a review of literature suggests that a rapid response to an incursion of this species might have had better results and a variety of control options is available. Note that Forrest et al. (2009) argue that controlling spread of *D. vexillum* in New Zealand was possible given that the species is typically restricted to artificial substrata. The species was also thought to have spread in New Zealand through the movement of mussel seedstock (Forrest & Hopkins 2013), and the control of spread through aquaculture is difficult due to lack of effective treatments.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*D. vexillum* is not native to Australia. There are no records of the species in Atlas of Living Australia (ALA 2017c) or NIMPIS (2017f).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	Human mediated invasion has likely spread *D. vexillum* globally (Lambert 2009). *D. vexillum* has poor natural dispersal spread, with larvae in the water column for less than a day (Osman & Whitlatch 2007 as cited in Herboug et al. 2009). The likelier pathway of spread is by vessels or aquaculture (Herboug et al. 2009). Fletcher et al. 2013 found that the species might disperse naturally hundreds of meters to kilometres. It is a fouling species that could survive in niche areas on a vessel. Transport via recreational vessels from New Zealand is likely (Glasby & Lobb 2008).
1I	The species has the potential to become established in Australian waters	True	Temperature tolerance for *D. vexillum* is within range for southern Australia (Glasby & Lobb 2008). The species has been documented in most temperate regions of the world, including East/West North America; north-west Europe, the United Kingdom, Ireland, New Zealand and Japan (see Stefanik et al. 2012).
2	This species progresses to Step 2 (all criteria are true).	False	*D. vexillum* does not pass Step 1: it would be difficult to accurately identify in the field (1D).

Neogobius melanostomus

Phylum: Chordata

Common name: Round goby

Status: Exotic

Assessed by Michelle Besley; reviewed by Sandra Parsons

Table G43 Step 1 assessment for *Neogobius melanostomus*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	False	*Neogobius melanostomus* is an estuarine and freshwater species; it can stay in freshwater but can tolerate range of salinities. It is able to colonize various habitats, from the freshwater of rivers or lakes to brackish waters with polyhaline (up to 37 ppt) salinities (Smirnov 1986). The species has colonised freshwater and brackish waters (Adrian-Kalchauser & Burkhardt-Holm 2016). In an experimental study by Karsiotis (2012) of salinity tolerances of *N. melanostomus*, no gobies were found to survive with salinities over 30 ppt, whereas all gobies survived at 0 ppt to 20 ppt. This suggests that oceanic salinities are fatal to the goby, whereas estuarine or river habitats would be suitable for the species. The impacts of the species are largely freshwater; therefore, the task group decided to refer the species to the freshwater task group.
1B	The species is not native.	True	*N. melanostomus* is not native to Australia. It is a native species in the Caspian, Black and Azov seas (Bala´zˇova´-L'avrincˇı´kova´ & Kova´c 2007).
1C	The species is not on the EPBC Act live import list.	True	*N. melanostomus* is not on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	*N. melanostomus* has a black spot on the on the first dorsal fin, and adults would be able to be detected in the field. However, juveniles are solid grey, which may be difficult to identify from other native gobies at this life stage. Species ID cards would need to be developed to help distinguish the species with other native gobies. An eDNA assay has been developed in Europe to detect *N. melanostomus* in river systems (Adrian-Kalchhauser & Burkhardt-Holm 2016). In Canada, the species was on an invasive watch list, and was first detected by an angler who contacted the invasive species hotline (Dimond et al. 2010).
1E	The species could feasibly be controlled in the environment.	True	*N. melanostomus* is a small benthic fish. The species is a bottom dweller and in its native range it occupies a variety of habitat sites including coarse gravel and shell and sandy inshore areas; in Europe, it occupies sandy–stony substrates, mussel beds, piers, and in the United States, occurs in cobble and sand substrates (Ray & Corkum 2001). In the Great Lakes of North America, the species spread to all lakes in five years; it also spread quickly in Poland (Corkum et al. 2004). However, it is thought that the pattern of spread is along shipping routes

Criterion code	Criterion	True or false	Justification
			(Kalchhauser et al. 2013). Further, *N. melanostomus* has found to have site fidelity in rocky substrates, and not move long distances (Ray & Corkum 2001). In Canada, *N. melanostomus* was discovered in a tributary and a rapid response was initiated. The rapid response, involving a chemical piscicide (rotenone) treatment was not successful in eradicating the species or preventing its spread into the lake. However, the rate of spread was reduced (Dimond et al. 2010). Other control options were examined, such as physical removal (traps), but were not chosen as were slow, labour intensive, expensive and will not achieve complete eradication. Rotenone was not specific and impacted other species. Rollo et al. (2007) reported *N. melanostomus* will approach a speaker emitting conspecific male calls in the field, and female round gobies showed significant attractions to speakers emitting conspecific male calls in the laboratory. Therefore *N. melanostomus* phonotaxis could be used to lure gravid females to traps. As the species spawns multiple times throughout late spring and summer, they should remain receptive to male calls and bioacoustic capture for the entire breeding season.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	*N. melanostomus* is thought to have been transported internationally by ballast water, as either eggs, juveniles or adults (Corkum et al. 2004). Kalchhauser et al. (2013) notes that *N. melanostomus* dispersal has followed shipping routes. Once arrived, it could spread on its own through connected systems.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*N. melanostomus* is not in Australia (NIMPIS 2017a). The species is found in Caspian, Black and Azov seas (freshwater/brackish) including estuaries and ascended tributaries. It is also found in the Baltic Sea (marine) and introduced to the Great Lakes (freshwater). In 1990, *N. melanostomus* was found outside the Ponto-Caspian basin—in the Gulf of Gdansk in the Baltic Sea. (Bala´zˇova´-L'avrincˇı´kova´ & Kova´c 2007). The species was also found in the River Lek (Netherlands) in 2004, the first record in the North Sea basin (van Beek 2006).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	Ballast water is thought to have transported *N. melanostomus* internationally (Corkum et al. 2004). As Karsiotis et al. (2012) note, ballast water exchanges are likely to be successful in preventing further spread of the species as the round goby cannot tolerate oceanic salinities.
1I	The species has the potential to become established in Australian waters	True	*N. melanostomus* has wide ecological tolerances and there is suitable habitat here in Australia. It is found in various habitats and has wide tolerances of temperature, water depths (mostly nearshore) and oxygen saturation (Bala´zˇova´-L'avrincˇı´kova´ & Kova´c 2007).
2	This species progresses to Step 2 (all criteria are true).	False	*N. melanostomus* does not pass Step 1: it is a (mainly) freshwater species (1A) and as such has been referred to the freshwater task group.

Siganus rivulatus

Phylum: Chordata

Common names: Marbled spinefoot, rabbitfish

Status: Exotic

Assessed by Michelle Besley; reviewed by Sandra Parsons

Table G44 Step 1 assessment for *Siganus rivulatus*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	Saoud et al. (2007) studied the salinity tolerances of *Siganus rivulatus* and found that the species is a highly euryhaline fish which has an optimal salinity level of 35 ppt.
1B	The species is not native.	True	*S. rivulatus* is not native to Australia. Its native range is from South Africa to the Red Sea, including Madagascar, the Comoros and Seychelles (Fricke 2010). Its known introduced range is the eastern and central Mediterranean (Galil 2006b).
1C	The species is not on the EPBC Act live import list.	True	*S. rivulatus* is not on the EPBC Act Live Import list. Other *Siganus* spp. are on the list, but *S. rivulatus* and *S. luridus* (Rabbit fishes) are excluded.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	*S. rivulatus* can be identified with high degree of taxonomic certainty. The species would be difficult to distinguish between some of the native species of rabbit fish in the field. While ID cards could possibly be prepared to distinguish from Australian species of rabbitfish, the general public would have difficulty and likely over-report native species sightings. Fishbase (n.d.) provides a description of the species: Upper body—grey, green or brownish, silvery below; iris—iridescent silver or golden. Body colour patterns extend to the fins. Spines slender, pungent and venomous. Preopercular angle 88°–96°; cheeks scaled; midline of thorax, isthmus and midline of belly without scales. Frightened fish become mottled or with six diagonal zones across side. Tip of broad-based flap of anterior nostril reaching at least halfway to orifice of posterior nostril.
1E	The species could feasibly be controlled in the environment.	True	The herbivorous species has been found to settle in protected shallow areas with hard substrate and algal communities; it is able to settle on a large range of substrates and habitats—from rock pools to muddy harbours and sea grass beds (Bariche et al. 2004). *S. rivulatus* forms schools of 50 to several hundred individuals usually in sheltered bays to depths of 60 m (Fricke 2010). No literature could be identified that documented any control attempts for *S. rivulatus*. The available control techniques may include chemical piscicides (rotenone) and other fishing techniques.

Criterion code	Criterion	True or false	Justification
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	*S. rivulatus* entered the Mediterranean after the opening of the Suez Canal (known as Lessepsian migrants) (Bariche et al. 2004). Ballast water management could be managed; translocation for aquaculture is regulated. The species is not a well-known recreational species or a pretty aquarium fish (limited incentive for deliberate translocation/release).
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*S. rivulatus* is not present in Australia.
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	*S. rivulatus* entered the Mediterranean after the opening of the Suez Canal (known as Lessepsian migrants) (Bariche et al. 2004). Wonham et al. (2000) detected the species in ballast water, which may suggest ballast is another potential vector. This pathway was also noted by Hayes & Sliwa (2003) in their study of identifying potential marine pests for Australia.
1I	The species has the potential to become established in Australian waters	True	*S. rivulatus* is both euryhaline and eurythermal—having a wide range of salinity tolerances (10 ppt to 50 ppt, optimal 35 ppt) (Saoud et al. 2007) and surviving temperatures between 15 °C and 35 °C, with optimal around 27 °C (Saoud et al. 2008). The species has successfully established in the Mediterranean and it could be feasible to establish here.
2	This species progresses to Step 2 (all criteria are true).	False	*S. rivulatus* does not pass Step 1: it would be difficult to accurately identify in the field (1D).

Styela clava

Phylum: Chordata

Common name: Clubbed tunicate

Status: Established

Assessed by Michelle Besley and Tim Glasby; reviewed by Sandra Parsons

Table G45 Step 1 assessment for *Styela clava*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Styela clava* is a marine species and not a freshwater species (GISD 2017m). In known distributions of the species on the Pacific coast, it has been reported at salinities varying from 22 ppt to 36 ppt, with adults unable to survive in salinities lower than 10 ppt, and larvae dying below 18 ppt (Cohen 2005 as cited in O'Loughlan et al. 2006).
1B	The species is not native.	True	*S. clava* is not native to Australia. It was first recorded in Australia in Hobsons Bay, Port Phillip Bay, Victoria in 1972 (NIMPIS 2017r; Holmes 1976; Keough & Ross 1999). It is native to Asia (Japan, Korea, northern China and the Russian Federation in the north-west Pacific) (Goldstein et al. 2011) and has been introduced to Australasia–Pacific, Europe, and North America (NZPA 2005; Davis & Davis 2007; Fuller 2005). *S. clava* was first recorded outside its native range in 1932, when it was found on the Californian coast (Clarke & Therriault 2007). It was introduced to Europe (Plymouth) in the 1950s, and invaded Ireland in the 1970s (Minchin & Duggins 1988). See Davis & Davis (2007) for information about the distribution and spread of *S. clava* in European waters.
1C	The species is not on the EPBC Act live import list.	True	*S. clava* is not on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	*S. clava* can be identified with a high degree of taxonomic certainty The species could be difficult to identify from natives in the field. Small specimens of *S. clava* up to 30 mm length may have no stalk and could possibly be confused with other Styela species (NIMPIS 2017r). However, adults can be identified in the field. Molecular tests are available (Goldstein et al. 2011).
1E	The species could feasibly be controlled in the environment.	True	A *S. clava* incursion could theoretically be controlled—if in a very early stage of invasion and detected on artificial structures. However, it would be impossible to control on a large scale. The species inhabits shallow waters in the sub-tidal zone. It is an epibenthic species, which attaches to solid structures, such as pylons, wharves, rocks, vessel hulls. Lutzen (1999) noted that the species occurs at higher densities on artificial structures compared to natural surfaces. The eggs and larvae are lecithotrophic and are planktonic for 24 hours to 28 hours at 20 °C, before settling, attaching and metamorphosing onto the substrate (Cohen 2005 as cited in Clarke & Therriault 2007). It is assumed, like many ascidians, that the maximum dispersal distance

Criterion code	Criterion	True or false	Justification
			from the adult is 10 m; therefore, the species has a short natural dispersal. The primary long-distance dispersal mechanism is therefore likely to be human-mediated. In the environment, hand-picking of the species and disposal can remove species in small areas (NIWA n.d.). However, in Washington, it was noted that whilst over a half a ton of the species was removed, it was not successful as the population was larger than thought (Clarke & Therriault 2007). Other control options for the species include exposure to high salinities, temperatures, acetic acid and air-drying on mobile infrastructure (NIWA n.d.; Forrest et al. 2007; Coutts & Forrest 2005; Piola et al. 2010). In situ, the species can be smothered (such as on pilings), or handpicked.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	*S. clava* is a fouling organism. Controls could be put in place for aquaculture infrastructure and commercial vessels to minimise movement to new estuaries to some extent, but recreational vectors are not easily controlled (this was the likely vector in Ireland; Minchin et al. 2006). The species has invaded many countries in northern and southern hemispheres, including New Zealand, and is native to Asia (CABI, 2017i) so there would be need to control both international and national vectors. The species may be transported with oyster movements. However, it can be controlled when de-fouling oysters, with a combination of salinity, temperature and air exposure, which kills the sea squirt but not the oysters (Eno et al. 1997 as cited in Clarke & Therriault 2007).
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	False	Where *S. clava* has been introduced recently, it has been argued that the species might have impacts on Aquaculture (MPI 2013; Çinar 2016). Like any fouling species (and its congener *S. plicata*), it can potentially cover large areas, but is mainly restricted to artificial structures, at least in Ireland, where it remains a decade after introduction (Minchin & Duggins 1988). The species was introduced into Australia over 40 years ago, yet there has been no action to control its spread within Victoria or New South Wales, nor any known controls to prevent it spreading to Tasmania or South Australia. The species is not causing any issues in New South Wales. Coleman et al. (2001) found small abundances of the species in Port Phillip Bay (as part of a baseline assessment for an aquaculture site). However, these abundances were no different from those for *S. plicata* and no mention was made of impacts of *S. clava* on aquaculture. The species has invaded many countries worldwide—including New Zealand—and is native to Asia (CABI 2017i), so there would be need to control both international and national vectors.
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	*S. clava* is widespread on artificial structures in Port Phillip Bay, where it has been present for over 40 years.
1L	The species is not widely cultivated in Australia.	True	*S. clava* is not cultivated in Australia; it is eaten in Korea (NIWA n.d.).

Criterion code	Criterion	True or false	Justification
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	True	*S. clava* is recorded from Victoria, Western Australia (ALA 2017f) and New South Wales (Russ 1977). It is likely to be able to survive in South Australia and Tasmania as it can tolerate temperatures ranging from –2 °C to 23 °C and salinity from 20 ppt to 32 ppt (Davis and Davis 2007).
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	*S. clava* has an abbreviated larval life stage (Lecithotrophic—yolk, not capable of feeding in the water column—approximately 5000 eggs, hatch after 12–15 h, larvae 0.85 mm, swim a little for a short period of time, attached to hard substrate) (Davis and Davis 2007). Egg and larvae are planktonic for 1 to 3 days (NIMPIS 2017r; Kashenko 1996). While both natural and human-aided vectors have been suggested to explain the long-range dispersal of *S. clava* (in England), the majority of the sites containing *S. clava* were commercial ports and harbours, which suggests shipping, may be an important dispersal vector. Many neighbouring small fishing harbours and marinas did not have the species (Davis and Davis 2007).
2	This species progresses to Step 2 (all criteria are true).	False	*S. clava* did not pass Step 1: pathways and vectors cannot feasibly be managed (1F); and there is unlikely to be national interest in containing the species' spread and improving its management (1J).

Styela plicata

Phylum: Chordata

Common name: Solitary ascidian

Status: Established

Assessed by Michelle Besley and Tim Glasby; reviewed by Sandra Parsons

Table G46 Step 1 assessment for *Styela plicata*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Styela plicata* is not freshwater and is abundant in harbours and marinas around the world. The species has been reported in Tampa Bay to occur in salinities ranging from full seawater to 20 ppt (Baker et al. 2004 as cited in Masterton 2007) and in salinities that fluctuate between 22 ppt and 34 ppt in Hong Kong (Thiyagarajan & Qian 2003).
1B	The species is not native.	False	*S. plicata* has been present in Australian waters since at least 1870s (Port Jackson, Heller 1878) (Kott 1985; Keough & Ross 1999). The species is abundant in harbours and marinas around the world, recorded from the temperate areas of the Atlantic Ocean and Mediterranean, eastern coast of North America (but not the western coast) and the West Indies (Kott 1985). It is also present in the West Indian Ocean, Hong Kong and

Criterion code	Criterion	True or false	Justification
			Japan (NIMPIS 2017s). It remains unclear where the native range for the species exists, but is potentially the northwest Pacific (de Barros et al. 2009; Pineda et al. 2011).
1C	The species is not on the EPBC Act live import list.	True	*S. plicata* is not on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	*S. plicata* can be identified with a high degree of taxonomic certainty. Individuals range in colour from light tannish white to grey. Thin red or purple stripes on the insides of the four-lobed siphons are evident as cross-shaped markings at the tips of the closed siphons. The species can be found single or in groups (Masterton 2007). The lack of systematic knowledge and available keys for species identification is a serious problem in ascidians (Zhan et al. 2015). Small specimens of *S. clava* up to 30 mm length may have no stalk and could possibly be confused with other *Styela* species. The test (protective covering, also called the tunic) of *S. clava* is leathery and the gut loop is simple and vertical, whereas the test of *S. plicata* is whitish, almost naked, tough but not leathery and the gut loop is deeply curved (Kott 1985; NIMPIS 2017s).
1E	The species could feasibly be controlled in the environment.	False	*S. plicata* is already recorded from all states and the Northern Territory, so is already in all potential jurisdictions where it could occur. Theoretically, the species could be controlled in a new area, if in a very early stage of invasion. However, it would be impossible to control on a large scale. The species is frequently found in estuarine environments, preferring brackish and polluted waters (de Barros et al. 2009). It is commonly found inhabiting marinas and harbours on warm and temperate oceans (Pineda et al. 2011). It can adhere to several substrates, particularly artificial ones. According to Pineda et al. (2011), all observations of the species have been found on man-made structures, except in Japan, where the species grows in natural habitats. There are methods for controlling most types of biofouling, such as acetic acid and air-drying (various sources, including Forrest et al. 2007; Coutts & Forrest 2005; Piola et al. 2010). Physical control may be possible, such as wrapping.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	*S. plicata* is a fouling organism. Anthropogenic vectors are the main pathway of dispersal for the species (Pineda et al. 2011). The species has a short larval duration and is unlikely to be transported long distances in the water column (Masterton 2007). Controls could be put in place for aquaculture infrastructure and commercial vessels to minimise movement to new estuaries to some extent, but recreational vectors not easily controlled. The species has invaded most countries throughout the world (Sanamyan & Monniot 2007).
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	False	*S. plicata* is extremely widespread, recorded in all states and the Northern Territory (Cardno 2015; ALA 2017g). The species is predominately found in disturbed environments and is present in virtually all commercial ports.
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	*S. plicata* is well established in Australia, as evidenced by its distribution.

Criterion code	Criterion	True or false	Justification
1L	The species is not widely cultivated in Australia.	True	There are no described uses for *S. plicata*; it is not known to be a fisheries/aquaculture species.
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	False	*S. plicata* is recorded in all states and the Northern Territory (Cardno 2015; ALA 2017g).
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	As for *S. clava*, *S. plicata* has a short larval life stage (Lecithotrophic yolk, not capable of feeding in the water column). The larva are short-lived and cannot swim, thus most spread is through human vectors (Zhan et al. 2015). Large-scale dispersal can thus only be attributed to human mediated transfers, resulting in widespread geographical distributions that we observe presently (Zhan et al. 2015). These human mediated pathways may include ballast water, sea chests, hull fouling, and aquaculture farming equipment vectors. Human-mediated introductions of invasive ascidians have been occurring with an increasing frequency (references within Zhan et al. 2015- multiple references). De Barros et al. (2009) found that commercial shipping is the most likely cause of the global distribution of the species.
2	This species progresses to Step 2 (all criteria are true).	False	*S. plicata* does not pass Step 1: it may be native (1B); it cannot feasibly be controlled in the environment (1E); pathways and vectors cannot feasibly be managed (1F); there is unlikely to be national interest in containing the species' spread and improving its management (1J); and the species is already established in all potential jurisdictions (1M).

Cnidaria

Carijoa riisei

Phylum: Cnidaria

Common names: Orange soft coral, snowflake coral, branched pipe coral

Status: Uncertain (established species screening used)

Assessed by Justin McDonald; reviewed by Sarah Graham and Sandra Parsons

Table G47 Step 1 assessment for *Carijoa riisei*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Carijoa riisei* has been documented as inhabiting marine environments (van Ofwegen 2010).
1B	The species is not native.	Unknown	*C. riisei* was originally described from the Caribbean and tropical Atlantic (Bayer 1961 as cited in Kahng et al. 2008), though Concepcion (2010), argues the origin of Carijoa is the Indo-Pacific region. The native range of *C. riisei* is described by Fofonoff et al. (2003) as extending from the Indian Ocean (Gulf of Oman and Mozambique) through to the western Pacific Ocean (Australia, Fiji and Tonga), but further taxonomic evaluation is still required. The species has been reported in India, where it is unclear if the species is native or introduced (Patro et al. 2015). The species was detected in Hawaii in 1972, where it is an invasive species. Within Australia, records indicate identifications in the Northern Territory, South Australia and New South Wales (Concepcion 2010). There are also reports of a similar 'look-a-like' species in Western Australian (Justin McDonald, pers. comm.). However, it remains unclear if the species is native to Australia or an established marine pest.
1C	The species is not on the EPBC Act live import list.	True	*C. riisei* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	*C. riisei* is difficult to distinguish from *Carijoa multiflora* (Concepcion et al. 2010), which are also present in Australian waters (see ALA 2017a). Concepcion (2008) questioned the taxonomy of some specimens of *C. riisei* and in a later study (Concepcion et al. 2010) indicated that *C. riisei* is native to the Pacific region. There are also reports of a similar looking species in Western Australia. However, the taxonomy has not been investigated (Justin McDonald, pers. comm.). Therefore, based on the available literature and the outcomes of the working group, *C. riisei* is likely to be an unresolved species complex and difficult to identify.
1E	The species could feasibly be controlled in the environment.	True	*C. riisei* is known to inhabit both reefs and artificial structures (metal, concrete, plastic rope) that are not exposed to direct sunlight (Patro et al. 2015). The species is found predominately in turbid coastal areas, most commonly on jetties and wrecks as fouling organisms (Padmakumar et al. 2011). *C. riisei* is highly

Criterion code	Criterion	True or false	Justification
			fecund, capable of single parent reproduction as well as having male, female and hermaphrodite colonies. It is also able to spread through runners and stolons into adjacent areas in all directions (CABI 2017b). Toonen et al. (2007) examined the possibility of fresh water as an option for eradication of *C. riisei*, which may be an option with wrapping of pylons.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	*C. riisei* is thought to have been distributed as hull fouling organisms on ships (Padmakumar et al. 2011).
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	False	Due to *C. riisei* requiring further taxonomic evaluation to examine its status, and the absence of documentation of the species negative impacts in Australia, it is unlikely that there is national interest with the current information to manage its spread into new jurisdictions.
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	Established populations of *Carijoa* species are present in Australian waters (Edgar 2000) and records indicate identifications of *C. riisei* in the Northern Territory, South Australia and New South Wales (Concepcion 2010). Further taxonomic evaluation is required to identify established populations in Australian waters and until such time eradication would be unlikely.
1L	The species is not widely cultivated in Australia.	True	*C. riisei* is not a cultivated species.
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	True	*C. riisei* is not documented in Victoria, Tasmania, Queensland or Western Australia. However, there are reports of 'look-a-likes' in Western Australia, where the taxonomy has not been investigated further (Justin McDonald, pers. comm.).
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	Concepcion et al. (2010) suggests the spread around the islands of Hawaii is largely due to maritime vectors, anthropogenic disturbance of eutrophication common to shipping ports. This is largely due to the presence of dense aggregations of the species in almost all Hawaiian commercial harbours. However, the species has not been detected on the hulls of vessels that travel inter-island.
2	This species progresses to Step 2 (all criteria are true).	False	*C. riisei* does not pass Step 1: it is presently unclear whether *it* is a native or introduced species in Australia (1B); it is difficult to accurately identify in the field (1D); and there is unlikely to be national interest in containing the species' spread and improving its management (1J).

Cordylophora caspia

Phylum: Cnidaria

Common name: Freshwater hydroid

Status: Established

Assessed by Justin McDonald; reviewed by Sarah Graham and Sandra Parsons

Table G48 Step 1 assessment for *Cordylophora caspia*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	The Australian Freshwater Invertebrates guide (AFIG 2013) describes *Cordylophora caspia* as tolerating both fresh water and mildly saline waters, occurring in still or flowing inland or coastal water. It is classed as euryhaline capable of tolerating a range of salinities over its geographic range. Tolerances can vary among populations, with some being freshwater only and some brackish, as a result of both genetics and acclimation (Kinne 1956; Arndt 1984). It has been described to survive between 0 ppt and 35 ppt as resistant stages, grow between 0.2 ppt and 30 ppt, and reproduce between 0.2 ppt and 2 ppt. In the environment, colonies are usually found in water of 1 ppt to 2 ppt where tidal influence is considerable, or between 2 ppt and 6 ppt where conditions are constant (Olenin 2006).
1B	The species is not native.	True	*C. caspia* is considered to be native to the Caspian and Black seas, but now has a cosmopolitan distribution (Aquenal 2002), with *C. caspia* recorded sporadically but widely in freshwater on all continents except Antarctica (Folino 2000). It is now established in Australia, with Briggs (1931) noting the presence of *C. lacustris* (a synonym of *C. caspia*) in 1922 in the Myall Lakes, New South Wales. However, the species may have been present earlier as Briggs notes *Cordylophora* from 1885, in Parramatta, described then as *C. whiteleggi* (a synonym of *C. caspia*), as well as from the River Inglis, Tasmania. Aquenal (2002) notes the species previously being identified in freshwater lakes in South Australia and Victoria. However, Wiltshire et al. (2010) could not find evidence to confirm the species' current presence in South Australia. The species is described in the Australian freshwater invertebrates guide, with the family *Clavidae* represented in Australian freshwaters by a single species *C. caspia* (AFIG 2013).
1C	The species is not on the EPBC Act live import list.	True	*C. caspia* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	*C. caspia*, a colonial hydroid, is a highly morphologically and ecologically variable species (Folino-Rorem et al. 2009). The species should be detectable when colony is large enough, but ability to identify in the field if small is questionable. It is known to be highly morphologically variable in response to salinity and temperature (Gili & Hughes 1995). Further, in winter colonies regress into dormant stolons, so may not be detectible for a significant portion of the year in some areas. Colour ranges from pale white to pink to light brown. To ascertain whether different species exist, morphological and genetic data need to be carefully

Criterion code	Criterion	True or false	Justification
			analysed (Folino 1999), as Folino-Rorem et al. (2009) found that there may be an indication of multiple evolutionary divergent lineages of *Cordylophora*.
1E	The species could feasibly be controlled in the environment.	False	Colonies typically grow on hard surfaces including rocks, pilings, and dreissenid mussel shells. However, the species is found on a range of habitats in its geographic range, including submerged and floating plants (Fofonoff et al. 2003). The species is a fouling organism so is likely to be detected first on artificial structures in the marine environment. As with many biofouling species, C. caspia can be controlled by wrapping, physical removal from ship hulls, increased temperature, oxygen deficiency (for 3–4 weeks), chemical chlorination (Olenin 2006). The species is dioecious and asexual, where asexual reproduction occurs by budding to form a new colony (Olenin 2006). The planktonic larvae developed during sexual reproduction are dispersed with water currents (Olenin 2006). The reproductive characteristics of C. caspia, particularly the planktonic stage, would make control difficult and only possible if detected early.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	The species is thought to be transported from the native Ponto-Caspian region via ship ballast and or hull fouling (Folino-Rorem et al. 2009). Given that the species is recorded in part of Australia already, control would need to be of all vectors—given small size of this species management may be tricky.
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	False	*C. caspia* has been recorded sporadically but widely in freshwater on all continents except Antarctica (Folino 2000). Its impacts are highly variable due to its size and often inconspicuous nature. It was considered a low priority pest by Hayes et al. (2005) in their assessment of priority pests. The CCIMPE review (Murphy & Paini 2010) found that the species had a moderate impact on the environment that was associated to changes in species composition when at high densities. A moderate impact on business was also recorded due to its biofouling capabilities particularly on intake pipes of power plants. These overseas impacts have not been documented in Australia, despite the species having been established for many years. The outcomes of the working group concluded that the impacts of this species to date, within Australia, are unlikely to be any more significant than native species within the same phylum and therefore is not of national interest to manage or reduce its spread.
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	As *C. caspia* has been found in several jurisdiction, for likely over 100 years (Briggs 1931), it is unlikely these populations could be eradicated. In the Port of Hobart survey in 2000–2002, the species was restricted to the artificial substrates at Macquarie wharf 2 at Sullivan's Cove; it is unknown if this population has spread, or if any eradication attempt was made.
1L	The species is not widely cultivated in Australia.	True	*C. caspia* is not a fisheries or aquaculture species.
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	True	*C. caspia* has not been documented from Northern Territory or Queensland. It is listed as present in Western Australia, Tasmania and New South Wales (Briggs 1931; Roch 1924; Halse et al. 2002; Pinder et al. 2005). The

Criterion code	Criterion	True or false	Justification
			species has been documented in freshwater lakes in Victoria (Aquenal 2002) and an unconfirmed presence in South Australia (Wiltshire et al. 2009).
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	The species is a great fouler of vessels. Shipping has spread *C. caspia* through much of the world and this species of hydroid is now known from temperate and tropical coastal regions of every continent (except Antarctica) (Fofonoff et al. 2003). The species is present in Tasmania, Western Australia, Victoria, New South Wales, and possibly South Australia (Wiltshire et al. 2009). It is unlikely to spread great distances by natural means.
2	This species progresses to Step 2 (all criteria are true).	False	*C. caspia* does not pass Step 1: it cannot feasibly be controlled in the environment (1E); pathways and vectors cannot feasibly be managed (1F); and there is unlikely to be national interest in containing the species' spread and improving its management (1J).

Tubastraea tagusensis

Phylum: Cnidaria

Common name: Tagusa daffodil coral

Status: Exotic

Assessed by Justin McDonald; reviewed by Sarah Graham and Sandra Parsons

Table G49 Step 1 assessment for *Tubastraea tagusensis*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Tubastraea tagusensis* inhabits marine environments (Miranda et al. 2016).
1B	The species is not native.	True	*T. tagusensis* is exotic to Australia. The species is native to the Galapagos, and has only been recorded as exotic to Brazil (Silva et al. 2011). The species was first reported in Brazil in the late 1980s on oil and gas rigs in the Campos basin, and has now spread 2,000 km along the coastline (Carlos-Junior et al. 2015).
1C	The species is not on the EPBC Act live import list.	True	*T. tagusensis* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty	False	*Tubastraea* spp. have poorly defined taxonomic characteristics and several unidentified morphotypes (Capel et al. 2016). *T. tagusensis* can be distinguished from the more closely related cosmopolitan *T. coccinea* by the smaller calicular diameter and greater size range of their corallites, yellow coloured coenosarc and presence of platform lobes (dePaula & Creed 2004), but the two species may potentially be misidentified (Fofonoff

Criterion code	Criterion	True or false	Justification
	• distinguishable from natives in the field.		et al. 2017). The working group concluded that it would be difficult to identify this species in the field with a high degree of taxonomic certainty.
1E	The species could feasibly be controlled in the environment.	True	In Brazil, *T. tagusensis* has invaded both natural habitats, including coral reefs, as well as artificial structures (Miranda et al. 2014). The species was found as fouling organisms on oil and gas rigs in Brazil, and has since established on and invaded tropical protected shallow-water rocky shores (de Paula & Creed 2004; Mantelatto et al. 2015). The highest densities of the species have been observed at depths of 1 m to 2 m (de Paula & Creed 2005 as cited in de Paula et al. 2014). The species is both simultaneously hermaphrodite and a brooder (De Paula et al. 2014). During spawning, the species produces large numbers of larvae which are dispersed by currents, with the planulae being highly buoyant (Miranda et al. 2016). The role of natural dispersal in the spread of the species in Brazil is unclear. Studies have shown that freshwater and wrapping are efficient in managing *T. tagusensis*. Exposure to freshwater for 45 minutes to 120 minutes resulted in 100% mortality (Moreira et al. 2014). Wrapping in plastic or raffia effectively killed all colonies within 7 days (Mantelatto et al. 2015).
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	Vectors seem to be primarily ship movement and oil or gas structures. However, since the introduction of *T. tagusensis* into Brazil, it has reported to have expanded its initial range 130 km from the late 1980s to 2010 (Mantelatto et al. 2015). Its range is now reported to be 2,000 km of the Brazilian coast (Carlos-Junior et al. 2015). The continuous invasion is thought to be due to several biological characteristics, including reproductive strategies and its ability to colonise different substrates and habitats (Miranda et al. 2016).
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*T. tagusensis* is not present in Australia. The species is native to the Galapagos, but has only been recorded as exotic to Brazil (Silva et al. 2011).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	*T. tagusensis* has short-lived larvae (3–14 days) (Reyes-Bonilla et al. 1997), which does not favour long-distance transport via ballast water (Ferreira et al. 2009). The introduction of *T. tagusensis* in Brazil was first recorded on oil and gas rigs and it is possible that a slow moving vessel or oil and gas platforms that travel within the thermal tolerances of the species, from a location with an established population, could act as a vector to transport this species to Australian waters.
1I	The species has the potential to become established in Australian waters	True	*T. tagusensis* is able to survive on a number of different substrates, including coral reefs, in the tropical waters of its introduced range in Brazil. Modelling has shown that it is likely the species has expanded its realised niche during the invasion process in Brazil (Carlos-Junior et al. 2015). The working group concluded that there was also the possibility for this species to establish on the Great Barrier Reef or similar coral reef habitats.
2	This species progresses to Step 2 (all criteria are true).	False	*T. tagusensis* does not pass Step 1: it would be difficult to accurately identify in the field (1D).

Echinodermata

Asterias amurensis

Phylum: Echinodermata

Common name: Northern Pacific seastar

Status: Established

Assessed by Sarah Graham and Jeff Ross; reviewed by Sandra Parsons

Table G50 Step 1 assessment for *Asterias amurensis*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Asterias amurensis* is not freshwater for any part of its life. O'Loughlin et al. (2006) provides a summary of the temperature and salinity tolerances of the species. The species salinity ranges are reported between 18.7 ppt and 41 ppt, with optimal salinity for larval development at 32 ppt. The species is reported to die at salinities lower than 8.75 ppt (Sutton & Bruce 1996 as cited in O'Loughlin et al. 2006).
1B	The species is not native.	True	*A. amurensis* is not native to Australia. Its native range is the coasts of northern China, North Korea, South Korea, Russia and Japan (MESA n.d.). The species was first recorded in Tasmania in 1986 (Buttermore et al. 1994). However, the species was initially mistaken for the endemic *Uniophora granifera* and was not correctly identified until 1992 (Ross et al. 2006).
1C	The species is not on the EPBC Act live import list.	True	*A. amurensis* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	*A. amurensis* can be identified with a high degree of taxonomic certainty (Australian Government 2015), including in the field. The native species *Uniophora granifera* is similar in appearance, though it has arms with rounded tips (DPIPWE 2016). In its native range in Japan, the starfish is extremely variable in morphology and genetically (Matsuoka & Hatanaka 1998).
1E	The species could feasibly be controlled in the environment.	True	*A. amurensis* could feasibly be controlled in the environment, depending on when and where it is found. There are a number of successful examples of local eradication (Henderson's lagoon, Tasmania; Tidal River, Victoria and Anderson's Inlet, Victoria). Ling et al. (2012) demonstrate that removal of aggregations associated with manmade structures can have a significant effect on population reproduction. The rapid response manual (Australian Government 2015) provides for a number of control options on vessels, aquaculture stock and equipment. The planktonic larvae of *A. amurensis* are long lived and can be spread large distance by currents, and eradication may not be feasible in open coastal environments (Australian Government 2015). The rapid response manual provides a number of scenarios where eradication is most likely feasible (Australian Government 2015).

Criterion code	Criterion	True or false	Justification
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	*A. amurensis* is carried in ballast water, which is thought to have been the introduction pathway of the species to Australia from Japan (as cited in Deagle et al. 2003), and is the most likely pathway for spread within Australia. The species is currently on the ballast water risk assessment list. The species may also be transported as fouling organisms. The rapid response manual provides a list of vectors and pathways of spread (Australian Government 2015).
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	True	The species is currently not found in South Australia, New South Wales and Western Australia, and environmental tolerances/modelling suggest it could establish in these states (Richmond et al. 2010). Due to the significant ecological impacts in established locations (including some economic impacts) (see Step 2), it is likely there would be continued interest in managing the species spread. This is also demonstrated by a national control plan already developed for the species (Aquenal 2008d) and a rapid response manual (Australian Government 2015).
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	Established populations of *A. amurensis* are found in Tasmania, extending from Banks Strait in the north to Recherche Bay in the south (Tasmanian Planning Commission 2009), and Port Philip Bay in Victoria (Parry & Cohen 2001a; Parry et al. 2003).
1L	The species is not widely cultivated in Australia.	True	No valuable human uses have been found for *A. amurensis* (GISD 2017a).
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	True	*A. amurensis* is currently not found in South Australia, New South Wales and Western Australia, and the species environmental tolerances/modelling suggest it could establish in these states (Richmond et al. 2010).
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	The dispersal west from Victoria/Tasmania to South Australia/Western Australia is more likely to occur anthropogenically via ballast, given ocean currents predominately are in opposite direction for larval dispersal.
2	This species progresses to Step 2 (all criteria are true).	True	*A. amurensis* meets all criteria for Step 1.

Table G51 Step 2 assessment for *Asterias amurensis*

Category code	Impact category	Criterion	True, false or unknown	Justification
2-0	Impact intensity (prerequisite)	The species is likely to reach high densities and maintain its invasiveness over time.	True	Population densities of *A. amurensis* overseas usually subside following major outbreaks. However, in Australia densities are often maintained at more than seven seastars per square metre, particularly where there is an abundant food supply (such as wharf piles, shellfish beds and shellfish aquaculture facilities) (DSE 2001 as cited in Australian Government 2015). The population in the Derwent Estuary in Tasmania and Port Phillip Bay in Victoria has fluctuated from the initial peak, but large populations have remained, and aggregations have maintained a large larval pool. The *A. amurensis* population in Derwent Estuary was estimated at more than 30 million in 1994 (Goggin 1998 as cited in Australian Government 2015), 3 million in 2000 (Ling 2000) and continues to constitute a significant component of macro-invertebrate biomass (more than 50%) in some locations within the estuary (Barret et al. 2010). In Port Phillip Bay, the population grew from 340,000 in 1995 to 96 million in 2000 (Parry & Cohen 2001a). Since 2000, the abundance of *A. amurensis* has declined but an established population remains in the Bay.
2A	Environmental impacts	The species negatively impacts the physical environment, biodiversity, ecological structure or function, or ecosystem services.	True	*A. amurensis* is an opportunistic predator, feeding on a variety of species including molluscs, ascidians, Bryozoans, sponges, crustaceans, polychaetes, fish and echinoderms (Hatanaka & Kosaka 1959). At high densities, *A. amurensis* has the potential to significantly affect soft sediment communities based on their feeding behaviours (Ross et al. 2001, 2003a, 2003b, 2004). By consuming a large quantity of bivalve species, which are functionally important on native assemblages, it is capable of altering habitats, food web dynamics and reducing species abundance and recruitment (Ross, Johnson & Hewitt 2003a).
		The species is likely to lead to the extinction or significant decline of a nationally protected or endangered species or community.	True	There has been links to the decline of the spotted handfish (endangered species) with the presence of *A. amurensis*, predominately via potential predation on egg masses (Bruce & Green 1998), although real evidence is equivocal.
		The species negatively impacts ecologically valuable marine species.	Unknown	No known evidence.
		The species negatively impacts places of nationally importance (relevant to the national identity).	Unknown	No known evidence.
		The species negatively impacts ecologically valuable places.	Unknown	No known evidence.

Category code	Impact category	Criterion	True, false or unknown	Justification
2B	Social impacts	The species negatively impacts infrastructure used by a significant proportion of people.	Unknown	No known evidence.
		The species negatively impacts amenity of resources used by a significant proportion of people over and extensive area.	Unknown	No known evidence.
		The species negatively impacts cultural assets valued by particular sections of the community.	Unknown	No known evidence.
2C	Business impacts	The species negatively impacts the profitability of recreational or commercial fisheries (including aquaculture).	True	Within its natural range in the northern Pacific, *A. amurensis* is considered a significant pest to the scallop and clam fisheries (Hatanaka & Kosaka 1959). An outbreak of *A. amurensis* in 1954 in Tokyo Bay caused a severe loss of marketable shellfish, which cost the industry more than 400 million yen (Kim 1986 as cited in Australian Government 2015). In Australia, there is limited evidence of impacts on commercial fisheries. However, it is known to prey on commercial species including scallops, mussels and clams (Lockhart & Ritz 2001; Ross, Johnson & Hewitt 2002). Tasmanian scallop farmers have reported heavy losses of stock due to predations by *A. amurensis* (Dommisse & Hough 2004) and snapper and gummy shark fishermen in Port Phillip Bay have also reported significant losses of bait as a result of the seastar (Dommisse & Hough 2004; Parry et al. 2003).
		The species negatively impacts the profitability of any other industry directly reliant on utilisation of and/or access to the marine environment.	Unknown	No known evidence.
		The species negatively impacts product acceptability in international markets and/or state/territory access to domestic markets.	Unknown	No known evidence.
		The species negatively impacts international and/or domestic shipping due to increased costs of meeting required biosecurity standards.	Unknown	No known evidence.

Category code	Impact category	Criterion	True, false or unknown	Justification
2D	Human health impacts	The species is likely to cause illness and/or physical injury to people resulting in deaths, permanent disabilities and/or substantial long-term health costs to the community.	False	*A. amurensis* is unlikely to cause any human health impacts.
3	Response	The species progress to Step 3, and recommendation for the APMPL.	True	*A. amurensis* has significant negative impacts on the environment (2A); and on businesses (2C).

Table G52 Step 3 assessment for *Asterias amurensis*

Criterion code	Criterion	True or false	Justification
3A	There is a national control plan for the species. (If false, provide details of known control options.)	True	There is the *National Control Plan for the Northern Pacific Sea Star, 'Asterias amurensis'* (Aquenal 2008d), and the *Northern Pacific Sea Star ('Asterias amurensis')—Australian Emergency Marine Pest Plan (EMPPlan) Rapid Response Manual* (Department of Agriculture and Water Resources 2015e).
3B	There are molecular tools for identifying the species.	True	Yes, see Bott et al. (2010).
3C	The potential distribution of the species has been modelled.	True	Richmond et al. (2010) modelled the potential distribution of the species in Australia. Dunstan & Bax (2007) and Bax & Dunstan (2004) modelled the potential range expansion in Southern Australia.

Mollusca

Anomia/Monia nobilis

Phylum: Mollusca

Common name: Golden oyster

Status: Exotic

Assessed by Richard Willan; reviewed by Sandra Parsons

Table G53 Step 1 assessment for *Anomia/Monia nobilis*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	All anomiids are marine for their entire life (Richard Willan [APMPL task group] pers. comm.).
1B	The species is not native.	True	Unable to decide as *Anomia/Monia nobilis* is presently inadequately characterised (Richard Willan [APMPL task group] pers. comm.).
1C	The species is not on the EPBC Act live import list.	True	*Anomia/Monia nobilis* is not on the EPBC Act Live Import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	This exotic species should never have made it through the preliminary screening (Richard Willan [APMPL task group] pers. comm.). *Anomia/Monia nobilis* is inadequately characterised morphologically and presently definable only by location (Hawaii). But even in Hawaii, where it is presently considered a pest, it should be treated as native, because it was first collected in Pearl Harbour over a century ago (Coles et al. 1999). It was initially described as an *Anomia*, looks like an *Anomia* and was classified as an *Anomia* by Dall et al. (1938) and by Kay (1979). Kay (1979) even depicted the larger of the syntypes in the Natural History Museum. However, Huber (2010: 619) re-examined the syntypes and concluded the arrangement of the muscle scars in the left valve corresponded with that of the genus *Monia*. The only report of '*Anomia nobilis*' being a marine pest came from Hawaii. However, Huber (2010: 619) concluded this species is endemic to the Hawaiian Islands. Some workers (including Carlton & Eldredge 2015) continue to argue that it is introduced to Hawaii on tenuous taxonomic grounds. They argue that because Huber (2010) also noted that '*Anomia caelata* Reeve, 1859 (= *Monia caelata*) is a junior synonym of *Anomia nobilis* Reeve, 1859' and that the former occurs in the Red Sea. Tan & Woo (2010) also recorded the former (as *Pododesmus caelatus*) from Singapore. These latter arguments by specialists in marine biosecurity (not taxonomy) merely demonstrate that *Anomia/Monia nobilis* is unrecognisable, both morphologically and biogeographically (Richard Willan [APMPL task group] pers. comm.).

Criterion code	Criterion	True or false	Justification
1E	The species could feasibly be controlled in the environment.	False	Given that *Anomia/Monia nobilis* cannot be distinguished morphologically from native Australian *Anomia* spp. (*A. trigonopsis*) or *Monia* spp. (*M. deliciosa, M. timida, M. zelandica*), it could not feasibly be controlled in the wild as the species would not be detected at the initial incursion stage.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	*Anomia/Monia nobilis* is a fouling organism (Hewitt et al. 2010). In an initial incursion shipping vectors could be managed. However it is highly unlikely that it would not be detected at such an early phase, so it is unlikely vectors could be controlled before it established. On occasions, most species of *Anomia* and *Monia* live on driftwood and other floating objects (like buoys), and these vectors would be more difficult to manage.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	False	*Anomia/Monia nobilis* is inadequately characterised morphologically and presently definable only by location (Hawaii).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	*Anomia/Monia nobilis* is a hull-fouling organism and could be transported by shipping (Hewitt et al. 2010).
1I	The species has the potential to become established in Australian waters	False	Establishment of *Anomia/Monia nobilis* in Australia is highly unlikely, as there are already six species of *Anomiidae* in Australian waters and some/all of them would outcompete it (Richard Willan [APMPL task group] pers. comm.).
2	This species progresses to Step 2 (all criteria are true).	False	*Anomia/Monia nobilis* does not pass Step 1: it is inadequatle defined and would be difficult to accurately identify in the field (1D); it could not feasibly be controlled in the environment (1E); and pathways and vectors could not feasibly be managed (1F).

Arcuatula senhousia

Phylum: Mollusca

Common name: Asian bag mussel

Status: Established

Assessed by Richard Willan; reviewed by Sandra Parsons

Table G54 Step 1 assessment for *Arcuatula senhousia*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Arcuatula senhousia* is marine throughout its entire life cycle. Willan (1985, 1987) and Cohen (2011) have characterised it morphologically and presented the synonymy. This species was universally known as *Musculista senhousia* until 2010 when its genus was changed to *Arcuatula*. In San Francisco Bay it has been collected at salinities of 17 ppt to 33 ppt and temperatures of 17 °C to 24 °C, and in southern California at 35 ppt to 37 ppt and 25 °C to 27 °C (Cohen 2011).
1B	The species is not native.	True	First records of *A. senhousia* in Australia are from the mid-1980s, but the founder population (probably in Port Phillip Bay) may have been present in the late 1970s (Robert Burn, pers. comm.). *A. senhousia* is (or has been) present in all possible Australian jurisdictions except New South Wales and Queensland. Its native range is the north-western Pacific Ocean (from Siberia to Singapore). The introduced/naturalised range for the invasive haplotype is the north-eastern Pacific Ocean (British Columbia to Baja California), southern temperate Australia, northern New Zealand, the Mediterranean and the north-eastern Atlantic Ocean (Galil 2006a; Richard Willan [APMPL task group] pers. comm.).
1C	The species is not on the EPBC Act live import list.	True	*A. senhousia* is not on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	There are several native Australian spp. of *Amygdalum* (*A. glaberrimum, A. beddomei* and *A. cf. japonicum*) that look very similar externally and require an experienced specialist to tell apart (Richard Willan [APMPL task group] pers. comm.). It was specifically characterised by Willan (1987) and Furlani (1996).
1E	The species could feasibly be controlled in the environment.	False	McEnnulty (2001) listed several possible options for control: air exposure/desiccation/freezing, commercial harvesting for food and fertiliser, dredging/beam trawling/mopping, heated water treatment (baths, spray). However, its habit of living inside 'nests' of self-produced byssal threads on the surface of, or below, soft substrates and seagrass meadows—as well as hard substrates like *Corallina* turfs—makes it almost impossible to detect, even when in great abundance (Willan 1985, Willan 1987; Crooks 1996). Soft substrates can rarely be sampled cheaply or cost effectively (Glasby & Lobb 2008). Adult *A. senhousia* is relatively small

Criterion code	Criterion	True or false	Justification
			(no larger than 30 mm shell length), which would further add to the difficulty of detection unless they had already become well established and reached large densities (Glasby & Lobb 2008).
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	The main vectors for *A. senhousia* are biofouling on ships' hulls and ballast water (Cohen & Carlton 1992 as cited in Hayes et al. 2005). Recreational vectors would be much more difficult to control.
Established species screening			
1J	There is likely to be national interest in containing the species' spread and improving its management.	False	Probably not, since *A. senhousia* has been in Australia for such a long time (approximately 45 years) and has nowhere lived up to the initial fears of 'smothering anaerobic mats'. It now occurs in all possible jurisdictions except for New South Wales and Queensland (but it has dwindled/died out naturally in South Australia and Western Australia [and Auckland], and only ever had low densities in Tasmania) (Richard Willan [APMPL task group] pers. comm.).
1K	There are populations established in the wild in Australia that are not feasible to eradicate.	True	If *A. senhousia* were of concern as a serious pest, attempts at eradicating the populations in Victoria, South Australia, Tasmania and Western Australia would have been undertaken. Clearly, eradication has been deemed unfeasible in all these jurisdictions.
1L	The species is not widely cultivated in Australia.	True	*A. senhousia* is not cultivated at all anywhere, in either its native or introduced range.
1M	The species is not established in all potential jurisdictions (to the best of our knowledge).	True	The only jurisdictions in which *A. senhousia* is presently not established are New South Wales and Queensland Glasby & Lobb (2008) concluded that of the 30 marine pests of concern they assessed, it was the most likely to arrive in New South Wales (specifically the Sydney estuaries) from overseas. They considered it likely to arrive in Botany Bay or Port Jackson from a port in southern Australia.
1N	Spread to new jurisdictions via anthropogenic vectors is likely to be greater than natural dispersal.	True	As far as I can ascertain, its spread has mostly been by anthropogenic means (such as shipping) (Richard Willan [APMPL task group] pers. comm.). Natural dispersion could occur by larvae and also transport by wading birds.
2	This species progresses to Step 2 (all criteria are true).	False	*A. senhousia* does not pass Step 1: it is difficult to accurately identify in the field (1D); it cannot feasibly be controlled in the environment (1E); pathways and vectors cannot feasibly be managed (1F); and there is unlikely to be national interest in containing the species' spread and improving its management (1J).

Crepidula fornicata

Phylum: Mollusca

Common name: Atlantic slipper limpet

Status: Exotic

Assessed by Richard Willan; reviewed by Sandra Parsons

Table G55 Step 1 assessment for *Crepidula fornicata*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	All stages in the *Crepidula fornicata* life cycle are marine. It can tolerate brackish water for short periods (Minchin 1999).
1B	The species is not native.	True	*C. fornicata* is not native to Australia. It was introduced into Great Britain at the end of the 19th century from North America, upon imported oysters *Crassostrea virginica* and has now spread extensively throughout Europe. Since then, it has invaded sheltered coasts of the north-west Atlantic Ocean and Mediterranean Sea (de Montaudouin et al. 1999). Its native range is the north-western Atlantic Ocean (St Lawrence Seaway to northern Mexico). Its introduced/naturalised range is the North American Pacific coast, Japan, northern Europe, the Mediterranean and Uruguay (Minchin 2008).
1C	The species is not on the EPBC Act live import list.	True	*C. fornicata* in not on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	*C. fornicata* could easily be confused with native calyptraeid (= slipper) limpets like *Ergaea walshi*, *Sigapatella calyptraeformis*, *Bostrycapulus pritzkeri* and *Crepidula immersa*, let alone nacellid and lottiid limpets (Richard Willan [APMPL task group] pers. comm.).
1E	The species could feasibly be controlled in the environment.	False	Being essentially subtidal and living on hard substrates—like mussel shells and wharf piles—means *C. fornicata* would be very hard to control in the environment. It could only be controlled in relatively small areas such as aquacultural leases. Interestingly, it is extremely intolerant of aromatic solvent-based dispersants used in oil spill clean-ups. During the clean-up response to the Torrey Canyon oil spill, nearly all the individuals were killed in areas close to dispersant spraying. The viscous oil was not readily drawn in under the edge of the shell by ciliary currents in the mantle cavity, whereas the detergent—alone or diluted in seawater—crept in much more readily and killed the animals (Zaiko 2005).
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	*C. fornicata* has been associated historically with the transport of oysters (see Question 1B), and present day aquaculture management practices should be able to control this spread. The species has also been

Criterion code	Criterion	True or false	Justification
			associated with hull fouling (see 1H). If the species was detected early enough, it may be managed to prevent the spread. However, as the species could easily be confused with natives, this may not be achievable.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*C. fornicata* is not present in Australian waters.
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	Using a deductive hazard assessment technique, Hayes & Sliwa (2003: Table 4) recognised *C. fornicata* as a potential 'next pest' for Australia. A few individuals were discovered amongst biofouling organisms on a pipe-laying vessel that was being inspected for marine pests prior to deployment in Australia. It is the largest pipe-laying vessel in the world. However, other species of *Crepidula* have also been found in similar associations on vessels—*Crepidula plana* was found on a dredge in Geraldton in 2002 (Wells et al. 2009) and *C. onyx* is regularly reported fouling vessels in Asia (Richard Willan pers. obs.).
1I	The species has the potential to become established in Australian waters	True	While *C. fornicata* could become established in Australia, Glasby & Lobb (2008) note that it would be unlikely to survive and reproduce in the Sydney estuaries (or further north) when water temperatures are warm. It cannot tolerate exposed coasts.
2	This species progresses to Step 2 (all criteria are true).	False	*C. fornicata* does not pass Step 1: it would be difficult to accurately identify in the field (1D); and it would be difficult to accurately identify in the field (1E).

Geukensia demissa

Phylum: Mollusca

Common name: Atlantic ribbed mussel

Status: Exotic

Assessed by Richard Willan; reviewed by Sandra Parsons

Table G56 Step 1 assessment for *Geukensia demissa*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	All stages of *Geukensia demissa* life cycle are marine. However, it can tolerate salinities from nearly fresh water up to 70 ppt, which is twice as salty as the open ocean. In California, it has been collected in salinities of 18 ppt to 34 ppt, and on one occasion at 6 ppt (Cohen 2011). It has been characterised morphologically by Fofonoff et al. (2003).
1B	The species is not native.	True	*G. demissa* is not native to Australia. Its native range is the temperate Atlantic coast of North America (southern Gulf of St. Lawrence to Palm Beach, Florida) (Carlton 1979). Its introduced/naturalised range is Texas, California (San Francisco to Newport Bay), Mexico (only Baja California), and (surprisingly) the tropical Atlantic coast of South America (Venezuela) (Baez et al. 2005; Richard Willan [APMPL task group] pers. comm.). However, that Venezuelan population requires verification as *G. demissa* and not the closely similar tropical species *G. granossisima* (Fofonoff et al. 2003).
1C	The species is not on the EPBC Act live import list.	True	*G. demissa* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	*G. demissa* has been characterised morphologically by Coan et al. (2000) and by Cohen (2011), and its ecology described by Bertness (1980). Its divaricating radial sculpture is identical to that of native Australian species of *Austromytilus*, *Brachidontes* and *Septifer*. Its habit of lying buried in intertidal mud is different.
1E	The species could feasibly be controlled in the environment.	False	There has been no attempt to control *G. demissa* in its introduced range documented in the literature. In North America, the ribbed mussel inhabits salt marsh communities, generally in aggregations (Bertness & Grosholz 1985). The species is most common in and amongst salt marsh sediment attached by byssal threads to each other and cord grasses (*Spartina* spp.) (Torchin et al. 2005). It would be impossible to control a species living on/in saltmarshes, mud flats and subtidally, particularly in association with native Australian flat oysters (*Ostrea angasi*). It is most abundant at the lower edge of salt marshes at about mid-tide level, but it also occurs in smaller numbers up into the high marsh zone above mean high water (Cohen 2011). Further south to the Carolinas and Florida, it occurs both subtidally on oyster reefs and intertidally in salt marshes (Cohen 2011).

Criterion code	Criterion	True or false	Justification
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	*G. demissa* was likely transported initially with Eastern American oysters for aquaculture (as cited in Torchin et al. 2005). Present-day aquaculture management practices should be able to control this spread. Regional introductions of the species are thought to be shellfish movements and ballast water (Carlton 1992 as cited in Torchin et al. 2005). In addition, migratory wading birds could carry live individuals clamped onto the feet or bills (Baez et al. 2005), which would make the species difficult to manage.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*G. demissa* is not present in Australian waters.
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	False	*G. demissa* was introduced to California in the 1800s, most likely with Eastern oysters transported for aquaculture (references cited within Torchin et al. 2005). It has been transported with live shipments of oysters across North America, but there are no reports of it invading Europe or Asia. The only vector that feasibly could transport it to Australia is ballast water and this is largely controlled.
1I	The species has the potential to become established in Australian waters	True	*G. demissa* could become established in Australia because of its wide salinity and temperature tolerances.
2	This species progresses to Step 2 (all criteria are true).	False	*G. demissa* does not pass Step 1: it would be difficult to accurately identify in the field (1D); it could not feasibly be controlled in the environment (1E); pathways and vectors could not feasibly be managed (1F); and. it is unlikely to be transported to Australia (1H).

Mya arenaria

Phylum: Mollusca

Common names: Soft-shell clam, eastern soft-shell clam, long-necked clam, steamer clam, sand gaper

Status: Exotic

Assessed by Richard Willan; reviewed by Sandra Parsons

Table G57 Step 1 assessment for *Mya arenaria*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	All stages of the *Mya arenaria* life cycle are marine. However, it tolerates a wide range of salinities and temperatures, and has high resistance to the presence of sulphides and low oxygen concentrations in the environment. The lowest mean salinity at which it exists in the Gulf of Bothnia is 4.5 ppt to 5.0 ppt. Adults can tolerate salinities down to 5 ppt and up to a maximum of 35 ppt (NIMPIS 2017j), and temperatures from –2 °C to 28 °C, and it can survive in an oxygen-free environment for up to 8 days (Cohen 2011).
1B	The species is not native.	True	*M. arenaria* is not native to Australia. It is native to the Atlantic coast of North America (from Labrador to Cape Hatteras) and the northern Pacific (from northern Alaska north of the Aleutian Peninsula, Korea, the Kurile Islands and northern Japan) (Cohen 2011). The species has been introduced to the Pacific Coast of North America (where it now occurs from central Alaska to northern California; Cohen 2011), and to Europe (where it now occurs in all European seas; Gollasch 2006). A few specimens have also been reported from the Saronikos Gulf in the Mediterranean Sea (Cohen 2011).
1C	The species is not on the EPBC Act live import list.	True	*M. arenaria* is not on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	*M. arenaria* has been well characterised by Cohen (2011). *M. arenaria* can be identified from natives in the field. It could only be confused with the native Australian, *Panopea australis*. Incidentally, in the North Atlantic Ocean, many problems are caused by different opinions about the assignment of specimens to either *M. arenaria*, *M. truncata* or *M. japonica* (Strasser 1999). For example, some authors claim the existence of M. arenaria on the Pacific west coast, while others argue that records from the north-western Pacific are misidentifications of *M. japonica* (Strasser 1999). According to Laursen (1966), all the records of *M. arenaria* he checked from within Arctic regions were actually *M. truncata* form ovata.
1E	The species could feasibly be controlled in the environment.	False	*M. arenaria* burrows into sediment (Strasser 1999). It is almost impossible to control a mudflat species [it lives in soft substrates ranging from hard stony sand to pure mud] with an extension into the subtidal. It is most abundant in intertidal and shallow subtidal areas, but it can also reach subtidal depths of up to 192 metres (Strasser 1999). The National Park Service (n.d.) states there are no controls for this species.

Criterion code	Criterion	True or false	Justification
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	*M. arenaria* has largely been transported by intentional transfer of live organisms by humans, which could be managed. It is also thought to be transferred in ballast (Strasser 1999), and this could be managed if detected.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*M. arenaria* is definitely not present in Australian waters, or any other southern hemisphere waters. Its history of translocation by humans is fascinating. It originated in the North Pacific during the Miocene and was already present on both Atlantic coasts in the Pliocene. However, it died out on the east coasts of the Pacific and the Atlantic during the glaciations of the Pleistocene. It is by far the earliest introduced species to the North Sea that scientists are aware of (Reise 1999). It was introduced by humans to the North Sea some 400 years to 700 years ago, and to the north-eastern Pacific 150 years ago. Petersen et al. (1999) dated shell material from Denmark to the thirteenth century and suggested that it could have been transferred to Europe by the Vikings. In the 1960s, it was also introduced to the Black Sea. There are several locations where it failed to establish. *M. arenaria* reported in Elkhorn Slough by 1916 are apparently no longer present (Wasson et al. 2001), and a bed reported in the Russian River had disappeared by 1920. *M. arenaria* from San Francisco Bay were planted in Santa Cruz prior to 1881 and in Morro Bay in 1915, but did not become established in either site. *M. arenaria* was first collected on the Pacific Coast in San Francisco Bay in 1874, having been accidentally introduced in shipments of Atlantic oysters (*Crassostrea virginica*) that began in 1869. By the 1880s, it was the most common clam sold in San Francisco Bay area markets (Stearns 1881), replacing the native rock cockle (*Protothaca staminea*) and bent-nosed clam (*Macoma nasuta*) in the marketplace, and by 1919, it was the only local clam sold. Public and private clam beds ranging in size from a few acres to hundreds of acres were established from Martinez and the Napa River to the South Bay, and fenced to keep out predatory bat rays and flounder. *Mya arenaria* was also transplanted to other Pacific Coast sites, undoubtedly with many unreported plantings. For example, Stearns (1881) asserted, 'it would be a wise, public spirited act if the captains of our coasting vessels would take the trouble and incur the slight expense attending the planting of this clam at such points as their vessels touch at in the ordinary course of business.' Spread to some sites may also have occurred accidentally through transplantings of oysters along the coast or with fresh introductions of oysters from the Atlantic. It is possible though less likely that its appearance in some locations resulted from deliberate introductions from the Atlantic, as some authors have claimed was attempted or occurred, or from the transport of small clams in ship fouling. It seems that many populations in the north-east and north-west Atlantic, both inside and outside cultivation are declining of their own accord; Maximovich & Guerassimova (2003) monitored populations in the White Sea for 20 years (1979–1999) and recorded no recruitment since 1988.
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	False	Transportation to other places is only by live individuals (byssally attached) and by deliberate movement of living individuals, both of which vectors are virtually impossible into Australia today (Richard Willan, pers.

Criterion code	Criterion	True or false	Justification
			obs.). This conclusion is contrary to that of Hayes & Sliwa (2003), who recognised *M. arenaria* as a potential 'next pest' for Australia. The species is thought to have been transported to the Black Sea by ballast water (Leppäkoski 1991), and this is an unlikely pathway to Australia due to the international ballast water controls.
1I	The species has the potential to become established in Australian waters	True	*M. arenaria* potential range has been mapped (Richmond et al. 2010), which highlights it could establish in the cooler waters of Tasmania, Victoria and part of South Australia.
2	This species progresses to Step 2 (all criteria are true).	False	*M. arenaria* does not pass Step 1: it could not feasibly be controlled in the environment (1E); and it is unlikely to be transported to Australia (1H).

Mytella charruana

Phylum: Mollusca

Common name: Charru mussel

Status: Exotic

Assessed by Richard Willan; reviewed by Sandra Parsons

Table G58 Step 1 assessment for *Mytella charruana*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	All stages of the *Mytella charruana* life cycle are marine. Experimentally, it can withstand salinity variations in the range of 14 ppt to 41 ppt (Ruelas-Inzuna & Paez-Osuna 2000; Yuan et al. 2010). Field observations by Spinuzzi et al. (2013) show that it can occupy field sites with salinities ranging from 0 ppt to 35 ppt; this indicates that it can tolerate wide ranges of salinities for at least short periods in its introduced range.
1B	The species is not native.	True	*M. charruana* is not native to Australia. Its native range includes both the central Pacific coast of America (Mexico to Peru plus the Galapagos Islands) plus and the Atlantic coast of America (Venezuela to Argentina) (Coan & Valentisch-Scott 2012). Its introduced/naturalised range is the south-eastern coast of the United States (only Florida and Georgia) (Lee 1987; Boudreaux & Walters 2006).
1C	The species is not on the EPBC Act live import list.	True	*M. charruana* is not on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty	False	*M. charruana* resembles the Australian native *Mytilus galloprovincialis* in size and shape (except that it is often incurved ventrally). Its external colour can vary from pale green to black, and it may be uniform or banded in a criss-cross pattern (Keen 1971; Boudreaux & Walters 2006; Coan & Valentisch-Scott 2012). The internal shell colour is deep purple (Keen 1971). *M. charruana* has indeed been confused with members of

Criterion code	Criterion	True or false	Justification
	• distinguishable from natives in the field.		the *Mytilus edulis/galloprovincialis* species group, which have an elongate anterior pedal retractor muscle scar. Thus it is close to *Mytilus* in shape but its differences are its mud habitat and subnacreous interior (Coan & Valentisch-Scott 2012).
1E	The species could feasibly be controlled in the environment.	False	This tropical mussel is a lagoonal species that typically occurs on mudflats, in shallow lagoons and attached to mangrove roots (Ruelas-Inzuna & Paez-Osuna 2000). *M. charruana* is known to settle on a number of natural and artificial substrates including *Crassostrea virginica* reefs, seagrass, wooden pilings, docks, boat ramps, concrete pilings (Gilg et al. 2010). There has been no documented control options. In some areas of its introduced range in the United States individuals have been physically removed (Boudreaux & Walters 2006).
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	False	Its spread via shipping could potentially be controlled but *M. charruana* also lives on driftwood and other floating objects in mangrove forests, and these vectors could not feasibly be managed, particularly if the species has established.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*M. charruana* is definitely not present in Australian waters.
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	*M. charruana* is thought to have been introduced to Florida via ballast water in an oil tanker (Lee 1987), and transport to Australia from tropical America in the ballast water of an oil tanker remains feasible, but unlikely. It is unlikely as there is no direct shipping from Venezuela or elsewhere in south-eastern United States to Australia.
1I	The species has the potential to become established in Australian waters	True	If it were introduced into Australia, *M. charruana* has the potential to become established. It could become established in many warm-temperate estuaries and lagoons along the eastern, southern, western, and even northern coastlines, but given its thermal tolerances in Florida, it probably could not form permanent populations in the colder temperate estuaries along Australia's southern coastline.
2	This species progresses to Step 2 (all criteria are true).	False	*M. charruana* does not pass Step 1: it would be difficult to accurately identify in the field (1D); it could not feasibly be controlled in the environment (1E); and pathways and vectors could not feasibly be managed (1F).

Mytilopsis leucophaeata

Phylum: Mollusca

Common names: Dark false-mussel, Conrad's false mussel, brackish water mussel

Status: Exotic

Assessed by Richard Willan; reviewed by Sandra Parsons

Table G59 Step 1 assessment for *Mytilopsis leucophaeata*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Mytilopsis leucophaeata* prefers freshwater to brackish environments, where it is generally restricted to oligo-mesohaline (0.5–15 ppt salinity) sections of estuaries. European populations occupy both freshwater and brackish estuarine habitats (Reise et al. 1999). It has been characterised morphologically and ecologically by Pathy & Mackie (1993) and by Therriault et al. (2012). *M. leucophaeata* is a temperate species, and its upper temperature tolerance has been established experimentally by Rajagopal et al. (2005). It is euryhaline and eurythermal (Kennedy 2011). The present research is equivocal regarding the species' ability to survive and reproduce in freshwater. Florin et al. 2013 notes *M. leucophaeata* can survive, but not reproduce in saline conditions above 20 ppt, and cannot survive in full seawater (salinity 35 ppt). Indeed, the species cannot reproduce in either fully freshwater or fully marine environments (Florin et al. 2013). Evidence suggests that the species cannot become established in fresh water (Cohen 2009). It can certainly complete its entire life cycle in freshwaters; Gloer & Zettler (2005) included it in their annotated checklist of the freshwater molluscs of Germany.
1B	The species is not native.	True	*M. leucophaeata* is not native to Australia. Its native range is the Gulf of Mexico and portions of the Atlantic coast of North America (Therriault et al. 2003; Kennedy 2011). Its introduced/naturalised range is North America (only the Hudson River and Chesapeake Bay), north-eastern Brazil (only the Pernambuco coast), and throughout Europe (North Atlantic Ocean, Mediterranean Sea, Baltic Sea, Black Sea, Caspian Sea) (Therriault et al. 2003; Kennedy 2011).
1C	The species is not on the EPBC Act live import list.	True	*M. leucophaeata* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	The species is able to be distinguished morphologically from natives. However, it is extremely difficult to distinguish from the exotic *M. sallei* (Richard Willan [APMPL task group] pers. comm.). One wonders what would happen if it were to occur at the same locality as *M. sallei* (Richard Willan [APMPL task group] pers. comm.). Florin et al. (2013) notes that it is similar in appearance to the Zebra Mussel (*Dreissena polymorpha*), and as such, has likely been misidentified as this species. Verween et al. 2010 (as cited in Florin

Criterion code	Criterion	True or false	Justification
			et al. 2013) provides a review of the differences in the morphology of adult and juvenile specimens of both species.
1E	The species could feasibly be controlled in the environment.	False	The experience in Europe has shown that *M. leucophaeata* cannot be feasibly controlled in estuaries or tidal creeks 'in the wild'. The species prefers hard substrates (Florin et al. 2013), either natural or artificial (Cohen 2009), preferring brackish to fully fresh water. The species is a dioecious broadcast spawner (Cohen 2009), with Verween et al. (2006) noting that the free swimming larvae are important for invasion, where the veligers can stay in the water column for up to two weeks before settlement. In the Archipelago Sea, it is unclear whether the spread of the population is occurring naturally from surrounding areas (over 120 km or 270 km away from known populations) or is being transported by anthropogenic means (Forrstrom et al. 2016). GISD (2017g) summarises potential control options for *M. leucophaeata*. However, these are largely for cooling systems, not 'the environment', where it has been shown to be more resistant to chlorination than other species, and as such continuous chlorination over time is necessary, although may be impractical. Another option, 'Degaclean' has found to be successful against embryos, but the cost may be prohibitive.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	*M. leucophaeata* is thought to have been spread by either ballast water or hull fouling (Laine et al. 2006; Cohen 2009). Its spread on shipping could potentially be controlled, but it also lives on driftwood and other floating objects (like buoys) and these vectors would be more difficult to manage.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*M. leucophaeata* is definitely not present in Australian waters.
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	False	*M. leucophaeata* is thought to have been spread in Europe through either ballast water or hull fouling (Laine et al. 2006; Cohen 2009). However, apparently not easily. The species was reported in Europe in 1835, but apparently received little attention until it became a biofouling problem (as cited in Florin et al. 2013). As the species cannot tolerate the salinities of ocean water, it is unlikely to arrive in Australia via hull fouling, and the current ballast water controls should prevent its entry. Although commercial and management organisations have moved oysters along the North American Atlantic coast since at least 1825, including from Chesapeake Bay to northern states, *M. leucophaeata* was not reported north of Chesapeake Bay until 1937 (Kennedy 2011). In this expanded northern range, it has not occurred in sufficiently high abundance as to be an industrial pest, or even noticed by the numerous agencies surveying benthic habitats there.
1I	The species has the potential to become established in Australian waters	Unknown	No known evidence.
2	This species progresses to Step 2 (all criteria are true).	False	*M. leucophaeata* does not pass Step 1: it could not feasibly be controlled in the environment (1E); and it is unlikely to be transported to Australia (1H).

Mytilopsis sallei

Phylum: Mollusca

Common name: Black-striped false mussel

Status: Exotic

Assessed by Richard Willan; reviewed by Sandra Parsons

Table G60 Step 1 assessment for *Mytilopsis sallei*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Mytilopsis sallei* has been reported at salinities 0 ppt to 27 ppt (NIMPIS 2017k). Though all stages of its life cycle it can tolerate greatly reduced salinity, but at no stage does it occur in completely freshwater. Densities of *M. sallei* decline dramatically in oceanic conditions (Astudillo et al. 2014).
1B	The species is not native.	True	*M. sallei* is not native to Australia. There was a major incursion in Darwin Harbour in 1999 (Willan et al. 2000; Bax et al. 2002) that was successfully eradicated at considerable expense. There have been several detections on (legally entering and illegally entering) vessels subsequently, but no establishment (Richard Willan [APMPL task group] pers. comm.). According to the present literature, its native range is the tropical central Atlantic Ocean (Caribbean Sea). Its introduced/naturalised range is Fiji, Indonesia, Singapore, Malaysia, Taiwan, India, and West Africa (Richard Willan [APMPL task group] pers. comm.). The species was first found in China, in Hong Kong Waters in 1980, and has spread along the south-eastern coast of mainland China (Morton 1980, Cai et al. 2006 as cited in He et al. 2016).
1C	The species is not on the EPBC Act live import list.	True	*M. sallei* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	*M. sallei* is able to be distinguished morphologically from all Australian natives; indeed Australia has no native species of either its family (*Dreissenidae*) or its superfamily (*Dreissenoidea*). Its relationship with the nominal species *M. adamsi* is contentious (Huber 2010). This taxonomic issue has caused considerable confusion recently. However, the decision has been made to continue using the name *M. sallei* in Australian literature (Richard Willan [APMPL task group] pers. comm.). *M. sallei* is extremely difficult to distinguish from the exotic *M. leucophaeata* (indeed the report by Galil & Bogi (2009) of *M. sallei* on the hull of a research vessel in the Mediterranean coast of Israel could be *M. leucophaeata*) (Richard Willan [APMPL task group] pers. comm.).
1E	The species could feasibly be controlled in the environment.	True	If it was detected early, *M. sallei* could be controlled. However, since it tolerates brackish conditions and man-made habitats, and can live on all substrates (Willan et al. 2000), it would be difficult to control in mangrove forests or in ports 'in the wild'. For the response to the *M. sallei* incursion in the gated man-made

Criterion code	Criterion	True or false	Justification
			marinas in Darwin, chlorine and copper sulphate was used for the successful eradication of the species, though it poisoned all the other species in the marinas (See 1G below).
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	It is possible the spread of *M. sallei* via shipping and recreational craft could be controlled, as it was in Darwin in 1999, but because it also lives on driftwood and other floating objects (like buoys) these vectors would be more difficult to manage.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	The species is not presently in Australian waters. In 1999, *M. sallei* was found in three, gated, man-made marinas in Darwin, where it had reached incredible densities in a few months. The marinas were artificial habitats with very low 'natural' conservation values. The Northern Territory Government made a rapid decision to use chemicals (chlorine and copper sulphate) to poison everything in the marinas to eradicate the entire populations. The eradication was undertaken successfully after one month with intense effort. This is one of very few examples of an introduced species having been successfully eliminated. Since then, *M. sallei* has been detected on a number of illegal foreign fishing vessels in Australian waters. These vessels were inspected before reaching port and destroyed at sea. So far, *M. sallei* has not been reintroduced into Australia (Wells et al. 2008).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	*M. sallei* could be easily transported into Australia as hull fouling on (legal and illegal) shipping. The incursion in Darwin in 1999 almost certainly arose through hull fouling on a recreational yacht coming from south-east Asia (Bax et al. 2002; Richard Willan [APMPL task group] pers. comm.).
1I	The species has the potential to become established in Australian waters	True	As was demonstrated very strongly by the incursion into Darwin in 1999, *M. sallei* has great potential to become established in Australian waters.
2	This species progresses to Step 2 (all criteria are true).	True	*M. sallei* meets all criteria for Step 1.

Table G61 Step 2 assessment for *Mytilopsis sallei*

Category code	Impact category	Criterion	True, false or unknown	Justification
2-0	Impact intensity (prerequisite)	The species is likely to reach high densities and maintain its invasiveness over time.	True	*Mytilopsis sallei* definitely maintains its invasiveness over time. Tan & Morton (2006) have summarised the sequence of invasions in ports throughout tropical Asia. Thirty years after its much-publicised introduction into Hong Kong (Morton 1987, 1989), it is uncommon there now and mainly restricted to biofouling communities within areas subject to intensive human activity and poor water quality (Astudillo et al. 2014). Its invasiveness is maintained though. There still

Category code	Impact category	Criterion	True, false or unknown	Justification
				seems to be unknowns regarding the reproductive biology of this species and its likely potential population densities (Summerson et al. 2013).
2A	Environmental impacts	The species negatively impacts the physical environment, biodiversity, ecological structure or function, or ecosystem services.	True	Initially it forms a 'densely populated band … up to several kilometres inland from the sea' (Tan & Morton 2006: 430) that excludes most other species, leading to a substantial reduction in biodiversity in infected areas and economic losses (Morton 1989; Subba Rao 2005; Lin & Yang 2006).
		The species is likely to lead to the extinction or significant decline of a nationally protected or endangered species or community.	True	It is highly likely that high densities of *M. sallei* could cause the extinction of locally endemic species that are confined to brackish water situations, of which many are already threatened by development (Richard Willan [APMPL task group] pers. comm.).
		The species negatively impacts ecologically valuable marine species.	Unknown	No known evidence.
		The species negatively impacts places of nationally importance (relevant to the national identity).	Unknown	No known evidence.
		The species negatively impacts ecologically valuable places.	Unknown	No known evidence.
2B	Social impacts	The species negatively impacts infrastructure used by a significant proportion of people.	True	The species would impact marinas, harbours and vessels with serious fouling issues. There would be serious consequences for shipping and many aquacultural industries (particularly prawn farming).
		The species negatively impacts amenity of resources used by a significant proportion of people over and extensive area.	True	The species would impact marinas, harbours and vessels with serious fouling issues. The example with Darwin showed that when the marinas were closed there was great hardship to a significant proportion of people.
		The species negatively impacts cultural assets valued by particular sections of the community.	Unknown	No known evidence.
2C	Business impacts	The species negatively impacts the profitability of recreational or commercial fisheries (including aquaculture).	True	Along with *Brachidontes pharaonis*, *M. sallei* is certainly a major pest for aquacultural facilities in Taiwan (Richard Willan, pers. obs.). The establishment of the species would cause serious consequences for shipping and many aquacultural industries (particularly prawn farming). An infestation of *M. sallei* in a prawn farm could have significant consequences.

Category code	Impact category	Criterion	True, false or unknown	Justification
		The species negatively impacts the profitability of any other industry directly reliant on utilisation of and/or access to the marine environment.	True	Murphy & Paini (2010) assessed the species as having an extreme impact on business.
		The species negatively impacts product acceptability in international markets and/or state/territory access to domestic markets.	Unknown	No known evidence.
		The species negatively impacts international and/or domestic shipping due to increased costs of meeting required biosecurity standards.	True	The Darwin example showed significant negative consequences for both international and domestic shipping due to the biosecurity risk that *M. sallei* posed.
2D	Human health impacts	The species is likely to cause illness and/or physical injury to people resulting in deaths, permanent disabilities and/or substantial long-term health costs to the community.	Unknown	No known evidence.
3	Response	The species progress to Step 3, and recommendation for the APMPL.	True	*M. sallei* has potential for significant negative impacts on the environment (2A); on society (2B); and on businesses (2C).

Table G62 Step 3 assessment for *Mytilopsis sallei*

Criterion code	Criterion	True or false	Justification
3A	There is a national control plan for the species. (If false, provide details of known control options.)	True	There is the *Black striped mussel ('Mytilopsis sallei') and Asian green mussel ('Perna viridis')—Australian Emergency Marine Pest Plan (EMPPlan) Rapid Response Manual* (Department of Agriculture and Water Resources 2015b).
3B	There are molecular tools for identifying the species.	True	Wong et al. (2011) sampled mitochondrial COI and found very high haplotype variability suggesting multiple invasions of Asia. It has been characterised genetically—a qPCR assay specifically for it has been developed by SARDI (Bott et al. 2012). Dias et al. (2017) have systematically undertaken taxonomic verification and vouchering of a reference specimen corresponding to a species-specific short (approximately 650 base pairs) DNA sequence or 'barcode' (mitochondrial COI).
3C	The potential distribution of the species has been modelled.	True	The potential distribution has been modelled using the invasive marine species mapping program (Richmond et al. 2010).

Perna canaliculus

Phylum: Mollusca

Common name: New Zealand green-lipped mussel

Status: Exotic

Assessed by Richard Willan and Anita Ramage; reviewed by Sandra Parsons

Table G63 Step 1 assessment for *Perna canaliculus*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Perna canaliculus* is not freshwater for any part of its life cycle. It is unable to tolerate salinities less than 25 ppt (Hickman et al. 1991; Jeffs et al. 1999). The species' normal temperature tolerances have been reported at 10 °C to 19 °C and salinity of 23 ppt to 35 ppt (Ogilvie et al. 2004 as cited in Glasby & Lobb 2008).
1B	The species is not native.	True	Though the fossil record indicates *P. canaliculus* lived in southern Australia approximately 10,000 years ago (George Kendrick pers. comm.; see Beu 2004; Wood et al. 2007), it is extinct there now and only lives in New Zealand. Its native range is throughout mainland New Zealand, but not the Chatham or subantarctic islands (Spencer et al. 2016).
1C	The species is not on the EPBC Act live import list.	True	*P. canaliculus* is not on the EPBC Act live import list. Presently, export of *P. canaliculus* constitutes up to 70% of total aquaculture production in New Zealand (Gribben et al. 2011). Carlton (1992) predicted its establishment in California where it is imported live daily in large numbers for human consumption. However, no published records of its establishment in California have confirmed that prediction.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	*P. canaliculus* is characterised morphologically by Powell (1979) and Furlani (1996). Even though live individuals can occasionally have a black periostracum, it could be easily separated from *Mytilus galloprovincialis* in Australia (Richard Willan [APMPL task group] pers. comm.).
1E	The species could feasibly be controlled in the environment.	True	Potentially, *P. canaliculus* could be controlled, but it maintains reservoir populations subtidally to over 50 metres (Jeffs 1999). It can also tolerate extreme wave exposure (Wilkens & Allen 2015). The mussel larvae settle primarily on filamentous structures such as algae, and then re-settle on hard substrates, either natural or artificial (Alfaro et al. 2006 as cited in McLeod et al. 2011). Therefore, control may be difficult.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	Hull fouling is a primary vector for the transport of *P. canaliculus*, as has been evidenced by numerous interceptions (Wilkens & Allen 2015). It is likely that this vector can be managed to prevent the spread of a species in an incursion. Due to the species' economic importance in New Zealand, if *P. canaliculus* were to establish in Australia illegal anthropogenic domestic spread would need to be monitored.

Criterion code	Criterion	True or false	Justification
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	Presently true. The first Australian record of *P. canaliculus* came from Bridport in Tasmania in 1876 (TMAG record) and it 'does not appear to have become well established' there (Furlani 1996). However, there have been numerous interceptions over the last 20 years (Wilkens & Allen 2015) and one population was established in the wild in Adelaide in 1996. It is not known whether this population died out of its own accord (as with *P. viridis*), or was completely removed during the eradication campaign (Richard Willan [APMPL task group] pers. Comm.). That P. canaliculus can survive in mid-ocean is demonstrated by the recent case of the SAXON ONWARD fishing vessel (Wilkens & Allen 2015).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	Hull fouling is a primary vector for the transport of *P. canaliculus*, as has been evidenced by numerous interceptions (Wilkens & Allen 2015).
1I	The species has the potential to become established in Australian waters	True	It is likely that *P. canaliculus* may survive in the cooler temperate waters of Australia, as the normal temperature tolerance range of the species is between 10 °C and 19 °C (Ogilvie et al. 2004 as cited in Glasby & Lobb 2008), particularly if deliberately imported for aquaculture. However, as Glasby & Lobb (2008) noted, it would be unlikely to survive and reproduce in the Sydney estuaries (or further north) when water temperatures are warm.
2	This species progresses to Step 2 (all criteria are true).	True	*P. canaliculus* meets all criteria for Step 1.

Table G64 Step 2 assessment for *Perna canaliculus*

Category code	Impact category	Criterion	True, false or unknown	Justification
2-0	Impact intensity (prerequisite)	The species is likely to reach high densities and maintain its invasiveness over time.	Unknown	*P. canaliculus* would survive if deliberately introduced for aquaculture, but the numerous incursions on ships entering Australia suggest it may not be able to withstand ocean voyages. Markula & Csurhes (2009) were unable to find evidence of *P. canaliculus* being a pest elsewhere.
2A	Environmental impacts	The species negatively impacts the physical environment, biodiversity, ecological structure or function, or ecosystem services.	True	True by analogy with the two other species in the genus. For example, in Florida, *Perna viridis* has altered biodiversity, primarily by out-competing or overgrowing native species (Boudreaux & Walters 2006; Spinuzzi et al. 2013).
		The species is likely to lead to the extinction or significant decline of a nationally protected or endangered species or community.	Unknown	No known evidence.

Category code	Impact category	Criterion	True, false or unknown	Justification
		The species negatively impacts ecologically valuable marine species.	Unknown	No known evidence.
		The species negatively impacts places of nationally importance (relevant to the national identity).	Unknown	No known evidence.
		The species negatively impacts ecologically valuable places.	Unknown	No known evidence.
2B	Social impacts	The species negatively impacts infrastructure used by a significant proportion of people.	Unknown	No known evidence.
		The species negatively impacts amenity of resources used by a significant proportion of people over and extensive area.	False	No known evidence.
		The species negatively impacts cultural assets valued by particular sections of the community.	Unknown	No known evidence.
2C	Business impacts	The species negatively impacts the profitability of recreational or commercial fisheries (including aquaculture).	True	It has the capacity to outcompete native Australian Blue Mussels (*Mytilus galloprovincialis*) and the potential to cause impacts on mussel industries in Victoria and Tasmania (Richard Willan [APMPL task group] pers. comm.). The introduction of *P. canaliculus* would pose a risk to Australian cultured mussels in that they also could be affected by the virus-like particles (see 2D).
		The species negatively impacts the profitability of any other industry directly reliant on utilisation of and/or access to the marine environment.	True	If it impacts aquaculture, then potentially *P. canaliculus* could have flow-on effects for related maritime industries (Richard Willan [APMPL task group] pers. comm.).
		The species negatively impacts product acceptability in international markets and/or state/territory access to domestic markets.	Unknown	No known evidence.
		The species negatively impacts international and/or domestic shipping due to increased costs of meeting required biosecurity standards.	Unknown	No known evidence.
2D	Human health impacts	The species is likely to cause illness and/or physical injury to people resulting in deaths, permanent disabilities and/or substantial long-term health costs to the community.	False	Although Murphy & Paini (2010) rated *P. canaliculus* as having extreme public health impacts, they are quite the opposite. The compound mercenine that is produced naturally by *P. canaliculus* has been promoted as beneficial for arthritis (Arthritis Research UK 2017). There are high mortalities of cultured populations in New Zealand attributed to virus-like particles (Webb 2007;

Category code	Impact category	Criterion	True, false or unknown	Justification
				Wilkens & Allen 2015) but there is no indication that these particles affect human health (Richard Willan [APMPL task group] pers. comm.).
3	Response	The species progress to Step 3, and recommendation for the APMPL.	True	*P. canaliculus* has potential for significant negative impacts on the environment (2A); and on businesses (2C).

Table G65 Step 3 assessment for *Perna canaliculus*

Criterion code	Criterion	True or false	Justification
3A	There is a national control plan for the species. (If false, provide details of known control options.)	False	No control options given.
3B	There are molecular tools for identifying the species.	True	Blair et al. (2006) have diagnosed the species of the genus *Perna* genetically using species-specific mitochondrial primers for the polymerase chain reaction. Wood et al. (2007) used mitochondrial gene COI plus nuclear genes ITS 1 and 2 to produce a molecular phylogeny for the genus *Perna*.
3C	The potential distribution of the species has been modelled.	False	Glasby & Lobb (2008) noted it would be unlikely to survive and reproduce in the Sydney estuaries (or further north) when water temperatures are warm. Markula & Csurhes (2009) suggested south-eastern Queensland could be its extreme northerly limit of distribution, and that if spawning did occur there, a high level of mortality would be expected.

Perna perna

Phylum: Mollusca

Common name: Brown mussel

Status: Exotic

Assessed by Richard Willan and Anita Ramage; reviewed by Sandra Parsons

Table G66 Step 1 assessment for *Perna perna*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	All stages of the *Perna perna* life cycle are marine. Adults can tolerate a temperature range of 10 °C to 30 °C and a salinity range of about 15 ppt to 50 ppt (Gulf States Marine Fisheries Commission 2005). Abada-Boudjema & Dauvin (1995) studied recruitment and lifespan of populations within its native range along the Algerian coastline.
1B	The species is not native.	True	*P. perna* is not native to Australia. The species is native in tropical and sub-tropical waters (Webb 2008). Its native range is Africa (from Mozambique to South Africa, plus parts of North Africa). A recent paper has argued that *P. perna* is a native of Brazil (Pierri et al. 2016). Its introduced/naturalised range is the north-western Indian Ocean, Gulf of Mexico, Caribbean Sea, and southwestern Atlantic Ocean (Uruguay) (Wells et al. 2008; Richard Willan [APMPL task group] pers. comm.). The range of *P. perna* does not currently overlap with that of *P. viridis* except in the southern Caribbean Sea (Agard et al. 1992; Rylander et al. 1996a; Baker et al. 2007).
1C	The species is not on the EPBC Act live import list.	True	*P. perna* is not on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	*P. perna* is able to be distinguished from Australian natives (Richard Willan [APMPL task group] pers. comm.). However, (green-shelled) individuals are almost impossible to separate from the exotic species *P. viridis* (Micklem et al. 2016).
1E	The species could feasibly be controlled in the environment.	True	In its native range of South Africa, *P. perna* occurs in dense aggregations attached to natural rocky substrates, where it dominates the lower eulittoral zone (Berry 1978; Bownes & McQuaid 2006), but it also colonises wood, concrete and steel. It is typically a mussel of wave exposed situations and it is even capable of growing on vertical rock faces exposed to the full force of breaking waves. However, it grows fastest on gently sloping, slow draining platforms (Berry 1978). GISD (2017i) reviewed chemical control options for *P. perna*, noting that Rajagopal (2003) found that continuous dosing of chlorine at a residual level of at least 1 mg/L is lethal.

Criterion code	Criterion	True or false	Justification
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	Hayes & Sliwa (2003) noted vessel fouling as a known vector for *P. perna*, with ballast water and translocations of fish and shellfish as other possible vectors. These could be managed in an incursion.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*P. perna* is not present in Australia.
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	Using a deductive hazard assessment technique, Hayes & Sliwa (2003: Table 4) recognised it as a potential 'next pest' for Australia. There have been a few instances over the last 15 years where live *P. perna* were intercepted on vessels bound for Australia or within ports in Australia. Similarly, live individuals were present on an oil rig in New Zealand in 2007, and cleaned in the water there (Hopkins et al. 2011). This was treated as a major marine pest emergency.
1I	The species has the potential to become established in Australian waters	True	Using a deductive hazard assessment technique, Hayes & Sliwa (2003: Table 4) recognised it as a potential 'next pest' for Australia. The species has wide temperature and salinity tolerances (see Segnini 1998 & Fofonoff et al. 2003).
2	This species progresses to Step 2 (all criteria are true).	True	*P. perna* meets all criteria for Step 1.

Table G67 Step 2 assessment for *Perna perna*

Category code	Impact category	Criterion	True, false or unknown	Justification
2-0	Impact intensity (prerequisite)	The species is likely to reach high densities and maintain its invasiveness over time.	True	The only reference I could find to a decrease in density of an established population was a mention in Carranza & Borthagaray (2009) of a 'natural' decline in Uruguay during the 1980s, but this decline was preceded and succeeded by increases in abundance (Richard Willan [APMPL task group] pers. comm.). Their main conclusion was that the effect of an invasive mussel is highly dependent on the receptive assemblage, and that the outcome of interspecific competition can be modulated by small-scale factors.
2A	Environmental impacts	The species negatively impacts the physical environment, biodiversity, ecological structure or function, or ecosystem services.	Unknown	No known evidence.

Category code	Impact category	Criterion	True, false or unknown	Justification
		The species is likely to lead to the extinction or significant decline of a nationally protected or endangered species or community.	Unknown	No known evidence.
		The species negatively impacts ecologically valuable marine species.	Unknown	No known evidence.
		The species negatively impacts places of nationally importance (relevant to the national identity).	False	No known evidence.
		The species negatively impacts ecologically valuable places.	False	No known evidence.
2B	Social impacts	The species negatively impacts infrastructure used by a significant proportion of people.	True	Damage has occurred in water-cooling systems of power plants located near the Gulf of Mexico coast (GISD 2017i). As a colony-forming mussel, this species aggregates on navigation buoys, causing them to sink. Hicks & Tunnell (1995) report that within four years of invasion, jetties, navigation buoys, petroleum platforms, wrecks and other artificial hard substrata—including natural rocky shores—had been colonised over a distance of 1,300 km. Hicks & Tunnell (1995) report that the species has the potential to dramatically increase the maintenance and/or replacement interval of offshore navigation aids, with the concern that heavy colonisation could sink navigational buoys leading to shipping safety issues.
		The species negatively impacts amenity of resources used by a significant proportion of people over and extensive area.	False	No known evidence.
		The species negatively impacts cultural assets valued by particular sections of the community.	False	No known evidence.
2C	Business impacts	The species negatively impacts the profitability of recreational or commercial fisheries (including aquaculture).	Unknown	Sa et al. (2007) conducted an elegant study in south-eastern Brazil, which demonstrated fouling reduced growth and biomass in cultivated *P. perna.* However, they questioned the benefits of removing the fouling organisms, both because the majority of fouling species are important feeding items to fishes, and the costs of fouling control added to the associated mussel spat loss make this fouling removal of questionable value.
		The species negatively impacts the profitability of any other industry directly reliant on utilisation of and/or access to the marine environment.	Unknown	No known evidence.

Category code	Impact category	Criterion	True, false or unknown	Justification
		The species negatively impacts product acceptability in international markets and/or state/territory access to domestic markets.	Unknown	No known evidence.
		The species negatively impacts international and/or domestic shipping due to increased costs of meeting required biosecurity standards.	Unknown	No known evidence.
2D	Human health impacts	The species is likely to cause illness and/or physical injury to people resulting in deaths, permanent disabilities and/or substantial long-term health costs to the community.	True	The mussel can harbor saxitoxin from consumed dinoflagellates. Its consumption has caused outbreaks of paralytic shellfish poisoning in Venezuela (Barbera-Sanchez et al. 2004). Tomalin & Kyle (2015) conducted a statistical analysis on deaths amongst recreational and subsistence collectors whilst harvesting *P. perna* in South Africa.
3	Response	The species progress to Step 3, and recommendation for the APMPL.	True	*P. perna* has potential for significant negative impacts on society (2B); on businesses (2C); and on human health (2E).

Table G68 Step 3 assessment for *Perna perna*

Criterion code	Criterion	True or false	Justification
3A	There is a national control plan for the species. (If false, provide details of known control options.)	False	No control plan has been developed to eradicate it or manage *P. perna* within any of the areas it has invaded (Richard Willan [APMPL task group] pers. comm.). A paper by Hopkins et al. (2011) describes a successful, once-off, dredge-based eradication of *P. perna* from a deep (approximately 44 m) soft-sediment environment in a sheltered coastal embayment in central New Zealand following the discovery of this species amongst biofouling organisms physically removed (defouled) in-water from a semi-submersible drilling rig. This eradication took place immediately after the rig was defouled. A total of 227 dredge tows covering approximately 94% of a 126 hectare target area were undertaken, and an estimated 35 tonnes of material defouled from the rig was dredged from the seabed and disposed of in terrestrial landfill.
3B	There are molecular tools for identifying the species.	True	Blair et al. (2006) have diagnosed the species of the genus *Perna* genetically using species-specific mitochondrial primers for the polymerase chain reaction. Wood et al. (2007) used mitochondrial gene COI plus nuclear genes ITS 1 and 2 to produce a molecular phylogeny for the genus *Perna*. Coelho et al. (2012) developed 10 polymorphic microsatellite markers. Micklem et al. (2016) used COI to distinguish *P. viridis* and *P. perna*. Dias et al. (2017) have systematically undertaken taxonomic verification and vouchering of a reference specimen corresponding to a species-specific short (approximately 650 base pairs) DNA sequence or 'barcode' (mitochondrial COI).

Criterion code	Criterion	True or false	Justification
3C	The potential distribution of the species has been modelled.	True	The species’ potential range has been mapped using the invasive species range mapping program (Richmond et al. 2010).

Perna viridis

Phylum: Mollusca

Common name: Asian green mussel

Status: Exotic

Assessed by Richard Willan; reviewed by Sandra Parsons

Table G69 Step 1 assessment for *Perna viridis*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Perna viridis* is marine for its entire life cycle. High salinity associated with open ocean is preferred and the species tends to be less abundant in estuaries where salinity is periodically low (McFarland et al. 2013). Csurhes (2015) report that the species becomes most abundant in optimal temperature and salinity conditions. Optimal salinity is in the range 27 ppt to 33 ppt, but the species can periodically tolerate salinity from 12 ppt to 80 ppt (Csurhes 2015). Spawning of the species may be induced by other spawning individuals or a drop in salinity (Stephen & Shetty 1981 as cited in Rajagopal et al. 2006). In the United States, a study by Urian et al. (2011) found that the threshold for survival of *P. viridis* populations is water temperatures between 10 °C and 14 °C. *P. viridis* occurs in areas where water temperature ranges from 11 to 35 °C, but 26 to 32 °C is optimal. Al-Barwani et al. (2011) described its reproductive biology as a prelude to opening an aquaculture industry in Malaysia. Using histological methodology, Bigatti et al. (2005) have described its reproductive cycle.
1B	The species is not native.	True	*P. viridis* is not native or established in Australia. Its native range is the Arabian Gulf, South China Sea and coastal southeast Asia (the Arabian Sea, China, India, Thailand, Malaysia and the Philippines). Its introduced/naturalised range is the coastal north-western Atlantic Ocean (south-eastern United States and Caribbean Sea), tropical Atlantic coast of South America (Venezuela), Japan, and South Africa (only Durban Harbour) (Richard Willan [APMPL task group] pers. comm.). The species was introduced into the coastal waters of Southwest Florida, where it was first reported in 1999 (see references within McFarland et al. 2013).
1C	The species is not on the EPBC Act live import list.	True	*P. viridis* is not on the EPBC Act live import list.

Criterion code	Criterion	True or false	Justification
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	True	The only Australian natives with which it could be confused are *Septifer bilocularis* and—even more unlikely—*Mytilus galloprovincialis*. However, *P. viridis* can be impossible to distinguish from (green-shelled colour forms) of the exotic *P. perna* (Micklem et al. 2016). The classic paper to distinguish the three recent species of *Perna* morphologically is that by Siddall (1980). Rajagopal et al. (2006) provides a list of diagnostic characters between *P. viridis* and *P. perna*.
1E	The species could feasibly be controlled in the environment.	True	*P. viridis* dominates rocky littoral and shallow sublittoral ecosystems (Rajagopal et al. 2006). The species fouls a variety of hard substrates including vessels, wharves, buoys, mariculture equipment (NIMPIS 2017l). There is a potential for the species to be controlled if first detected in these locations. However, if Florida is used as an example, the founder population was so abundant when it was discovered that eradication was not an option (Ludyanskiy et al. 1999; Fajans & Baker 2003). GISD (2017j) in a review of potential management options specifies that chlorination has been found to be successful. However, this has typically been performed for biofouling control of power plants.
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	Hayes & Sliwa (2003) note the possible vectors of *P. viridis* as biofouling and ballast water. The principal vector enabling spread is domestic shipping and potentially this can be controlled. Extensive inspections of vessels and manual removal of mussels probably led to the successful eradication of a wild population in Trinity Inlet in 2007 (Anita Ramage, pers. comm.).
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*P. viridis* is not established in Australian waters at present. The breeding population in Trinity Inlet (Stafford et al. 2007) possibly died out of its own accord (Richard Willan [APMPL task group] pers. comm.).
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	Using a deductive hazard assessment technique, Hayes & Sliwa (2003) recognised it as a potential 'next pest' for Australia. There are numerous instances of *P. viridis* arriving in Australian waters on vessel hulls and barges from Southeast Asia, sometimes in the thousands. If Florida is used as an example, *P. viridis* has dispersed extensively from the point of introduction in Tampa Bay (Boudreaux & Walters 2006), so much so that there are now dense populations throughout the entire bay (Baker et al. 2006). The species is thought to have been introduced to the United States from the Trinidad area, through either ballast or as hull fouling (see references within McFarland et al. 2013).
1I	The species has the potential to become established in Australian waters	True	If it were deliberately imported for aquaculture. The species inhabits tropical and subtropical climates, mainly marine intertidal, subtidal and estuarine environments with high salinity (Rajagopal et al. 2006). The species occupies midlittoral and sublittoral zones, often in dense populations. It grows on rocky surfaces and submerged artificial structures such as wharves, pilings, buoys and breakwaters (Rajagopal et al. 2006). The reasons for its apparent inability to survive after accidental transport on seagoing vessels are still mysterious. Mareike et al. (2016) found individuals on vessel hulls had a low body condition index (BCI) and were intolerant of low dissolved oxygen levels. They suggested that the risk of establishment of *P. viridis*, when

Criterion code	Criterion	True or false	Justification
			transported as hull fouling, is relatively low unless environmental conditions in the introduced area are highly preferable—that is, eutrophic with rich phytoplankton availability.
2	This species progresses to Step 2 (all criteria are true).	True	*P. viridis* meets all criteria for Step 1.

Table G70 Step 2 assessment for *Perna viridis*

Category code	Impact category	Criterion	True, false or unknown	Justification
2-0	Impact intensity (prerequisite)	The species is likely to reach high densities and maintain its invasiveness over time.	True	No literature I could find indicates otherwise (Richard Willan [APMPL task group] pers. comm.). This is despite its introduction into Florida 30 years ago (Griffiths et al. 1992; Ingrao et al. 2001). It appears to have maintained its initial density and invasiveness, and continued to spread (Agard et al. 1992; Rylander et al. 1996b; Baker et al. 2007).
2A	Environmental impacts	The species negatively impacts the physical environment, biodiversity, ecological structure or function, or ecosystem services.	True	Yes, by changing water quality.
		The species is likely to lead to the extinction or significant decline of a nationally protected or endangered species or community.	Unknown	No known evidence.
		The species negatively impacts ecologically valuable marine species.	True	If Florida is used as an example, *P. viridis* has altered biodiversity, primarily by out-competing or overgrowing native species (Boudreaux & Walters 2006; Spinuzzi et al. 2013). Since 2002, the species has displaced approximately half the native oyster populations (*Crassostrea virginica*) in Tampa Bay (references cited within McFarland et al. 2013). *C. virginica* is described as a ‘keystone species’, and where *P. viridis* displaces *C. virginica*, the species does not provide the same quality of habitat that is required for many estuarine species (references cited within McFarland et al. 2013).
		The species negatively impacts places of nationally importance (relevant to the national identity).	Unknown	No known evidence.
		The species negatively impacts ecologically valuable places.	Unknown	No known evidence.

Category code	Impact category	Criterion	True, false or unknown	Justification
2B	Social impacts	The species negatively impacts infrastructure used by a significant proportion of people.	True	*P. viridis* is capable of recruiting in very large densities on a number of fixed and floating hard substrata including vessels, wharves, buoys, mariculture equipment (Commonwealth of Australia 2015). *P. viridis* has fouled the intake pipes of power plants in India, Japan and Florida and navigational buoys in China, where its biomass can reach 72 kg/m^2 (Csurhes 2015). Morton (1996) thought that all three species of *Perna* must be considered potential nuisance species, if introduced outside their natural ranges. *P. viridis*, for example, is a serious fouler of the cooling conduits of the Madras Atomic Power Station at Kalpallam on the eastern coast of India where it is controlled by heat treatment or chlorination (Morton 1996).
		The species negatively impacts amenity of resources used by a significant proportion of people over and extensive area.	False	No known evidence.
		The species negatively impacts cultural assets valued by particular sections of the community.	False	No known evidence.
2C	Business impacts	The species negatively impacts the profitability of recreational or commercial fisheries (including aquaculture).	Unknown	No known evidence.
		The species negatively impacts the profitability of any other industry directly reliant on utilisation of and/or access to the marine environment.	True	*P. viridis* has the potential to impact oysters in the wild. In Florida, it has smothered and displaced reefs of native oysters (*Crassostrea virginica*) (Baker & Benson 2002; McFarland et al. 2013; Csurhes 2015).
		The species negatively impacts product acceptability in international markets and/or state/territory access to domestic markets.	Unknown	No known evidence.
		The species negatively impacts international and/or domestic shipping due to increased costs of meeting required biosecurity standards.	True	If an infestation of *P. viridis* resulted in a port being closed for control this could lead to significant negative impacts for shipping. Under the proposed new domestic ballast water management arrangements domestic ships moving from an infested port to a ‘clean’ port will be required to manage their ballast water (Anita Ramage, pers. comm.).
2D	Human health impacts	The species is likely to cause illness and/or physical injury to people resulting in deaths, permanent disabilities and/or substantial long-term health costs to the community.	True	*P. viridis* is an effective bioaccumulator, accumulating pollutants in the environment and causing human health problems by food poisoning (CABI 2017h). *P. viridis* can sometimes contain a potent toxin called saxitoxin, which is produced by certain dinoflagellates, upon which it feeds (Csurhes 2015).

Category code	Impact category	Criterion	True, false or unknown	Justification
3	Response	The species progress to Step 3, and recommendation for the APMPL.	True	*P. viridis* has potential for serious negative impacts on the environment (2A); on society (2B); on businesses (2C); and on human health (2D).

Table G71 Step 3 assessment for *Perna viridis*

Criterion code	Criterion	True or false	Justification
3A	There is a national control plan for the species. (If false, provide details of known control options.)	True	There is the *Black striped mussel ('Mytilopsis sallei') and Asian green mussel ('Perna viridis')—Australian Emergency Marine Pest Plan (EMPPlan) Rapid Response Manual* (Department of Agriculture and Water Resources 2015b).
3B	There are molecular tools for identifying the species.	True	Blair et al. (2006) have diagnosed the species of the genus *Perna* genetically using species-specific mitochondrial primers for the polymerase chain reaction. Wood et al. (2007) used mitochondrial gene COI plus nuclear genes ITS 1 and 2 to produce a molecular phylogeny for the genus *Perna*. Micklem et al. (2016) used COI to distinguish *P. viridis* and *P. perna*. Dias et al. (2017) have systematically undertaken taxonomic verification and vouchering of a reference specimen corresponding to a species-specific short (approximately 650 base pairs) DNA sequence or 'barcode' (mitochondrial COI).
3C	The potential distribution of the species has been modelled.	True	The potential distribution has been modelled using the invasive marine species mapping program (Richmond et al. 2010).

Potamocorbula amurensis

Phylum: Mollusca

Common name: Amur River clam

Status: Exotic

Assessed by: Richard Willan, reviewed by Sandra Parsons

Table G72 Step 1 assessment for *Potamocorbula amurensis*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	All stages in the *Potamocorbula amurensis* life cycle are marine. It has been well characterised morphologically by Carlton et al. (1990), Nichols et al. (1990), Furlani (1996), Coan et al. (2000: 479), Cohen (2011) and Thompson & Parchaso (2012). Its reproductive biology has been investigated by Nicolini & Perry (2000). It has been collected at sites in San Francisco Bay with salinities of 1 ppt to 33 ppt, though long-term survival is greatest above 5 ppt. Spawning and fertilisation require 5 ppt to 25 ppt and are most successful at 10 ppt to 15 ppt. In San Francisco Bay, *P. amurensis* has been collected at temperatures ranging from 8 °C on subtidal bottoms in the winter to 23 °C on intertidal flats in the summer, which is within the 0 °C to 28 °C temperature range suggested by its latitudinal range in Asia (Cohen 2011).
1B	The species is not native.	True	*P. amurensis* is not native to Australia. Its native range is southern Siberia south of about 53°N, Japan, Korea and China to about 22°N (Cohen 2011). Its introduced/naturalised range is the temperate north-western Pacific (only California) (Carlton et al. 1990; Nichols et al. 1990). It was first recorded in San Francisco Bay in 1986 (Carlton et al. 1990).
1C	The species is not on the EPBC Act live import list.	True	*P. amurensis* is not on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	*P. amurensis* is unlikely to be distinguished from natives in the field. It is very similar to native Australian species of *Corbulidae* (several spp.), Myidae (genus *Cryptomya*) and (some) Mactridae (particularly the genus *Spisula*) (Richard Willan [APMPL task group] pers. comm.).
1E	The species could feasibly be controlled in the environment.	False	*P. amurensis* occurs primarily in the subtidal areas on soft substrates (mud, sand, peat, and clay) (Carlton et al. 1990). It is highly unlikely that any species living primarily in subtidal soft sediments (Cohen 2011) could be controlled. Soft substrates can rarely be sampled cheaply or cost effectively (Glasby & Lobb 2008). Adult *P. amurensis* is relatively small (no larger than 30 mm shell length), which would further add to the difficulty of detection unless they had already become established and reached large densities (Glasby & Lobb 2008). Dredging, beam trawling and mopping as control options have been found to be unsuccessful in the case of

Criterion code	Criterion	True or false	Justification
			the *P. amurensis*. Dredging is unlikely to succeed as a control option due to very high densities and the small size of this species (GISD 2017h).
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	*P. amurensis* most likely arrived in San Francisco Bay as larvae discharged from a ship's ballast tank (Cohen 2011), and ballast water appears to be the main method of dispersal. It is unlikely to be transported by migratory wading birds clamped onto the feet or bills, as is the situation with the invasive mussel *Geukensia demissa* (Richard Willan [APMPL task group] pers. comm.).
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*P. amurensis* is definitely not present in Australian waters.
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	False	*P. amurensis* most likely arrived in San Francisco Bay as larvae discharged from a ship's ballast tank (Cohen 2011). Present day ballast water controls should prohibit the species from arriving in Australia.
1I	The species has the potential to become established in Australian waters	True	Richmond et al. (2010), using the invasive species range mapping program, showed that *P. amurensis* could establish in all states of Australia, but not the Northern Territory.
2	This species progresses to Step 2 (all criteria are true).	False	*P. amurensis* does not pass Step 1: it would be difficult to accurately identify in the field (1D); it could not feasibly be controlled in the environment (1E); and it is unlikely to be transported to Australia (1H).

Rapana venosa

Phylum: Mollusca

Common name: Rapa whelk

Status: Exotic

Assessed by Richard Willan; reviewed by Sandra Parsons

Table G73 Step 1 assessment for *Rapana venosa*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	All stages of *Rapana venosa* life cycle are marine. It has been characterised morphologically by Abbott & Dance (1990). It is a prolific, extremely versatile species tolerating low salinities, water pollution and oxygen deficient waters. All larval stages exhibit 48-hour tolerance to salinities as low as 15 ppt with minimal mortality. Below this salinity, survival grades to lower values. Percentage survival of *R. venosa* larvae is significantly less at 7 ppt than at any other salinity. There were no differences in percentage survival at salinities greater than 16 ppt (Mann & Harding 2003). Mann & Harding (2003) proposed that salinity tolerance is the dominant response controlling the potential dispersal (= invasion) range of the species into the estuaries of the Atlantic coast of the United States from the current invading epicentre in the southern Chesapeake Bay. In its native Korean range, *R. venosa* demonstrates large annual temperature tolerances (from 4 °C to 27 °C) (Chung et al. 1993 as cited in Mann & Harding 2000). It may migrate to warmer, deeper waters in winter thereby evading cool surface waters (GISD 2017k). An informative video showing its impact on the Black Sea is posted on YouTube (Türk Deniz Araştırmaları Vakfı (TÜDAV) / Turkish Marine Research Foundation 2014).
1B	The species is not native.	True	*R. venosa* is not native to Australia. Its native range is the coastal waters of the north-western Pacific Ocean (the Sea of Japan, the Yellow Sea, the East China Sea and the Bohai Sea) (Ghisotti 1974; Chandler et al. 2008; Koutsoubas & Voultsiadou-Koukoura 1991). However, it is included in Russia's Red Book as threatened with extinction. Since the 1940s, its introduced/naturalised range is Europe (the Black Sea, the Sea of Azov, the Mediterranean Sea, the Tyrrhenian Sea, the Adriatic Sea, the Aegean Sea, and off the coasts of France and the Netherlands), north-eastern Atlantic Ocean (Chesapeake Bay and Virginia), and south-eastern Atlantic Ocean (Rio de la Plata between Uruguay and Argentina) (Ghisotti 1974; Chandler et al. 2008; Koutsoubas & Voultsiadou-Koukoura 1991). Wilson's (1994: 47) comment under *Rapana rapiformis* 'The species has been introduced into the Black Sea, where it is thriving (pers. comm. Emily Vokes)' relates to *R. venosa* and not the native Australian *R. rapiformis* (Richard Willan pers. obs.).
1C	The species is not on the EPBC Act live import list.	True	*R. venosa* is not on the EPBC Act live import list.

Criterion code	Criterion	True or false	Justification
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	Although *R. venosa* could be identified with a high degree of certainty by an experienced taxonomist, it is unlikely to be distinguished from the native species *Rapana rapiformis* and *Rapa rapa* in the field. Conceivably, any large wide-mouthed neogastropod snail—such as *Mancinella*, *Drupa clathrata* and *Pugilina cochlidium*—could be mistaken for it (Richard Willan [APMPL task group] pers. comm.).
1E	The species could feasibly be controlled in the environment.	False	The rapid spread of *R. venosa* to many different parts of the globe must have been achieved by dispersal via ballast water. There is a large body of literature demonstrating that because it is almost exclusively subtidal and infaunal it would be 'almost impossible' to remove completely. It favours sandy bottoms where individuals can burrow, thus the seafloor of the southern North Sea is a very suitable habitat (Kerckhof et al. 2006). However, it also colonises hard substrates (GISD 2017k). As with many introductions, the probability of observing the initial colonisers is minimal. The cryptic nature of *R. venosa* contributes to the improbability of observing individuals until they are large and imposing members of the benthic community (ICES 2004).
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	Planktonic larvae could be translocated in ships' ballast waters around Australia. Historically, the transport of egg masses with marine farming products has been the most likely source of domestic translocation, but that vector should be managed given current aquacultural practices (CIESM 2016).
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*R. venosa* is not present in Australian waters.
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	False	Most translocations of *R. venosa* has resulted from ballast water and poor aquaculture practices, both of which should be managed in Australia with current practices. Accidental introductions of its egg cases with aquaculture products is possible (Kerckhof et al. 2006) and accidental introductions of its egg cases in hull fouling is also remotely plausible (Kerckhof et al. 2006).
1I	The species has the potential to become established in Australian waters	True	Because of the species' broad environmental tolerances and ability to be transported by several vectors, *R. venosa* has the potential to be spread in Australian waters.
2	This species progresses to Step 2 (all criteria are true).	False	*R. venosa* does not pass Step 1: it would be difficult to accurately identify in the field (1D); it could not feasibly be controlled in the environment (1E); and it is unlikely to be transported to Australia (1H).

Semimytilus algosus

Phylum: Mollusca

Common name: Pacific mussel

Status: Exotic

Assessed by Richard Willan; reviewed by Sandra Parsons

Table G74 Step 1 assessment for *Semimytilus algosus*

Criterion code	Criterion	True or false	Justification
1A	The species is not freshwater for the whole of its life.	True	*Semimytilus algosus* is marine for all stages of its life cycle. It has been characterised morphologically by Soot-Ryen (1955), Kensley & Penrith (1970), de Greef et al. (2013) and Bigatti et al. (2014). The later authors undertook a histological analysis of its reproductive stages.
1B	The species is not native.	True	*S. algosus* is not native to Australia. Its native range is the temperate Pacific coast of South America (Peru and Chile). Its introduced/naturalised range is the temperate Atlantic coast of southern Africa (South Africa and Namibia) (Richard Willan [APMPL task group] pers. comm.), where the species has been present in Namibia since the 1930s (see Bigatti et al. 2014; de Greef et al. 2013), and was first reported from South Africa in 2009 (Mead et al. 2011).
1C	The species is not on the EPBC Act live import list.	True	*S. algosus* is not listed on the EPBC Act live import list.
1D	The species is: • identifiable with a high degree of taxonomic certainty • distinguishable from natives in the field.	False	*S. algosus* is neither identifiable with a high degree of taxonomic certainty nor distinguishable from Australian natives in the field. It has been characterised by Coan & Valentisch Scott (2012). It exists as two morphotypes—a thick, smooth shell and a thinner, ridged shell—and therefore, there would inevitably be taxonomic uncertainty. The thick-shell morphotype is mostly found on rocky platforms, whereas the thin one is found on emergent rocks (Invasive Species South Africa 2016). Because of this variability of shape and thickness, it would inevitably be confused with the native *Mytilus galloprovincialis*. Its similarity to *M. galloprovincialis* means it would not be recognised until too late. Thin-shelled morphs would be confused with native *Modiolus* spp.
1E	The species could feasibly be controlled in the environment.	False	Control in the environment would be unlikely because new incursions of *S. algosus* would not be recognised early enough. It dominates the intertidal range of wave-exposed coastlines in its introduced South Africa (de Greef et al. 2013). Despite its reproductive mode (lacking free-swimming larvae), it has spread some 500 km along the western (Atlantic) coast of South Africa from Groenriviersmond in the north to Bloubergstrand in the south (Invasive Species of South Africa 2016).

Criterion code	Criterion	True or false	Justification
1F	Vectors or pathways could feasibly be managed to prevent the spread of the species.	True	*S. algosus* is thought to be transported by either hull fouling or ballast water (Bigatti et al. 2014; Mead et al. 2011; de Greef et al. 2013) rather than natural dispersal.
Exotic species screening			
1G	The species is not known to be present in Australian waters.	True	*S. algosus* is not present in Australia.
1H	The species could feasibly be transported to Australia via an anthropogenic vector.	True	The only vector that could transport *S. algosus* to Australia would be an anthropomorphic one. Mead et al. (2011) notes the species may be transported by ballast water or hull fouling, and the introduction to South Africa is likely to have been the result of human-mediated vectors rather than natural dispersal from Namibia (de Greef et al. 2013). The discovery of live individuals within the sea chests of a squid-fishing vessel at Nuevo Gulf, northern Patagonia (Argentina) (Bigatti et al. 2014) has demonstrated one means of spread and capacity for long-distance dispersal. These authors found it remarkable that *S. algosus* was able to recruit and grow on the vessel when it was anchored in Peru and then to survive the long trip to Argentinian Patagonia. Moreover, the sampled individuals were reproductively active, with some ready to spawn and others spawning.
1I	The species has the potential to become established in Australian waters	True	If it were to arrive in Australia, *S. algosus* could certainly be established in cold temperate areas such as those of Tasmania, Victoria and South Australia. The vectors that could transport the species do exist within Australia.
2	This species progresses to Step 2 (all criteria are true).	False	*S. algosus* does not pass Step 1: it would be difficult to accurately identify in the field (1D); and it could not feasibly be controlled in the environment (1E)

Glossary

Term	Definition
ABARES	Australian Bureau of Agricultural Resource Economics and Sciences
APMPL	Australian Priority Marine Pest List
CCIMPE	Consultative Committee on Introduced Marine Pest Emergencies
EPDNS	Established Pests and Diseases of National Significance
MPSC	Marine Pest Sectoral Committee
NEBRA	National Biosecurity Response Agreement
NIMPIS	National Introduced Marine Pest Information System

References

Abada-Boudjema, Y & Dauvin, J 1995, 'Recruitment and lifespan of two natural mussel populations *Perna perna* (Linnaeus) and *Mytilus galloprovincialis* (Lamarck) from the Algerian coast', *Journal of Molluscan Studies*, vol. 61, pp. 467–481.

Abbott, IA & Huisman, JM 2004, *Marine Green and Brown Algae of the Hawaiian Islands*, Bishop Museum Press, Honolulu.

Adrian-Kalchhauser, I & Burkhardt-Holm, P 2016, 'An eDNA assay to monitor a globally invasive fish species from flowing freshwater', *PLoS ONE*, vol. 11, e0147558.

Agard, J, Kishore, R & Bayne, B 1992, '*Perna viridis* (Linnaeus, 1758): first record of the Indo-Pacific green mussel in the Caribbean (Mollusca: Bivalvia)', *Caribbean Marine Studies*, vol. 3, pp. 59–60.

Ahyong, ST 2005, 'Range extension of two invasive crab species in eastern Australia: *Carcinus maenas* (Linnaeus) and *Pyromaia tuberculata* (Lockington)', *Marine Pollution Bulletin*, vol. 50, pp. 460–462.

ALA 2017a, Atlas of Living Australia, accessed 26 April 2017.

——2017b, 'Austromegabalanus psittacus' (Molina, 1782), Atlas of Living Australia, accessed April 2017.

——2017c, 'Didemnum vexillum', Atlas of Living Australia, accessed 26 April 2017.

——2017d, 'Pseudopolydora paucibranchiata', Atlas of Living Australia, accessed 20 April 2017.

——2017e, 'Sabella spallanzanii', Atlas of Living Australia, accessed 26 April 2017.

——2017f, 'Styela clava' Herdman 1981, Atlas of Living Australia, accessed 20 April 2017.

——2017g, 'Styela plicata, (Lesueur, 1823), Atlas of Living Australia, accessed 20 April 2017.

Aldridge, D, Madhyastha, A & Van Damme, D 2012, 'Corbicula fluminea', The IUCN Red List of Threatened Species 2012, e.T155736A735697, accessed 15 May 2017.

Allen, FE & Ferguson Wood, EJ 1950, 'Investigations on underwater fouling. II The biology of fouling in Australia: results of a year's research', *Australian Journal of Marine and Freshwater Research*, vol. 1, pp. 92–105.

Allen, FE 1953, 'Distribution of marine invertebrates by ships', *Australian Journal of Marine and Freshwater Research*, vol. 4, pp. 307–319.

Anderson, DM 2009, 'Approaches to monitoring, control and management of harmful algal blooms (HABs)', *Ocean Coast Management*, vol. 52, pp. 342.

ANSTF 2002, *A Draft National Management Plan for the Genus Eriocheir*, prepared by the Chinese mitten crab Control Committee for the Aquatic Nuisance Species Task Force.

Aquenal 2001, *Exotic marine pests survey, Port of Launceston, Tasmania*, report prepared by Aquenal Pty Ltd for Port of Launceston Pty Ltd.

——2002, *Exotic Marine Pests Survey, Port of Hobart, Tasmania*, final report prepared for the Hobart Ports Corporation Pty Ltd, Hobart.

——2008a, National Control Plan for the European Fan Worm, 'Sabella spallanzanii', report prepared for the Department of Agriculture and Water Resources, Canberra.

——2008b, National Control Plan for the European green shore crab, 'Carcinus maenas', report prepared for the Department of Agriculture and Water Resources, Canberra.

——2008c, National Control Plan for the Japanese Seaweed, 'Undaria pinnatifida', report prepared for the Department of Agriculture and Water Resources, Canberra.

——2008d, National Control Plan for the Northern Pacific seastar, 'Asterias amurensis', prepared for the Department of Agriculture and Water Resources, Canberra.

Araujo, R, Violante, J, Pereira, R, Abreu, H, Arenas, F & Sousa-Pinto, I 2011, 'Distribution and population dynamics of the introduced seaweed *Grateloupia turuturu* (Halymeniaceae, Rhodophyta) along the Portuguese coast', *Phycologia*, vol. 50, no. 4, pp. 392–402.

Arthritis Research UK 2017, Green-lipped Mussel, accessed 23 May 2017.

Arthur, T, Summerson, R, & Mazur, K 2015, *A comparison of the costs and effectiveness of prevention, eradication, containment and asset protection of invasive marine pest incursions* ABARES report prepared for the Department of Agriculture and Water Resources, Canberra.

Arthur, T, Zhao, S, Caley, P, Robinson, A, Gregg, M & McCrudden, R 2015, *Updating the methods for ballast water risk table construction*, report on CEBRA project 1301C to the Department of Agriculture and Water Resources, Canberra.

Astudillo, JC, Wong, JCY, Dumont, CP, Bonebrake, TC & Leung, KMY 2014, 'Status of six non-native marine species in the coastal environment of Hong Kong, 30 years after their first record', *BioInvasion Records*, vol. 3, pp. 123–137.

Baez, M, Severeyn, Y & Severyn, H 2005, 'Ciclo reproductivo de *Geukensia demissa* (Bivalvia: Mytilidae) en la playa de Nazaret, El Mojan, Estado Zulia, Venezuela', *Ciencias Marinas*, vol. 31, pp. 111–118.

Baker, P & Benson, B 2002, 'Habitat and ecology of green mussels, *Perna viridis*, in Florida', *Journal of Shellfish Research*, vol. 21, pp. 424–425.

Baker, P, Barber, B, Fajans, J & Baker, P 2006, 'Life history characteristics of the non-native green mussel (*Perna viridis*) in Tampa Bay, Florida', abstracts of the 2006 Annual Meeting of the National Shellfisheries Association, Monterey, California, March 26–30.

Baker, P, Fajans, JS, Arnold, WS, Ingrao, DA, Marelli, D & Baker, SM 2007, 'Range and dispersal of a tropical marine invader, the Asian green mussel, *Perna viridis*, in subtropical waters of the south-eastern United States', *Journal of Shellfish Research*, vol. 26, no. 2, pp. 345–355.

Bala´z˘ova´-L’avrinc˘ı´kova´, M & Kova´c, V 2007, ‘Epigenetic context in the life history traits of the round goby, *Neogobius melanostomus*’, in JA Drake (eds), *Springer Series in Invasion Ecology*, vol. 2, University of Tennessee, Knoxville, Tennessee.

Barbera-Sanchez, A, Soler, JF, Astudillo, LR & Chang-Yen, I 2004, ‘Paralytic shellfish poisoning (PSP) in Margarita Island, Venezuela’, *Revista de Biologia Tropical*, vol. 52, supplemental 1, pp. 89–98.

Bariche, M & Letourneur, Y 2004, ‘Temporal fluctuations and settlement patterns of native and Lessepsian herbivorous fishes on the Lebanese coast (eastern Mediterranean)’, *Environmental Biology of Fishes*, vol. 70, pp. 81–90.

Barret, N, Edgar, G, Zagal, C & Jones, OHE 2010, *Surveys of intertidal and subtidal biota of the Derwent estuary*, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart.

Bax, N & Dunstan, PK 2004, *Minimising Impacts of the North Pacific Seastar in Australia*, final report to the Australian Government National Heritage Trust.

Bax, N, Hayes, K, Marshall, A, Parry, D & Thresher, R 2002, ‘Man-made marinas as sheltered islands for alien marine organisms: establishment and eradication of an alien invasive species’, in CR Veitch & MN Clout (eds.), *Turning the Tide: The Eradication of Invasive Species*, International Union for the Conservation of Nature, Gland, Switzerland, and Cambridge, England, pp. 26–39.

Bax, N, Williamson, A, Aguero, M, Gonzalez, E & Geeves, W 2003, ‘Marine invasive alien species: a threat to global biodiversity’, *Marine Policy*, vol. 27, pp. 313–323.

Bellan, G 2017, ‘Polydora ciliata’ (Johnston, 1838), in G Read, K Fauchald (eds), World Polychaeta Database, accessed through World Register of Marine Species 15 May 2017.

Bentley, MG 2011, ‘The Global Spread of the Chinese mitten crab *Eriocheir sinensis*’, in Galil, BS, Clark, PF & Carlton, JT (eds.), *In the Wrong Place—Alien Marine Crustaceans: Distribution, Biology and Impacts*, Springer Netherlands, Dordrecht, pp. 107–127.

Berdalet, E, Fleming, LE, Gowen, R, Davidson, K, Hess, P, Backer, LC, Moore, SK, Hoagland, P & Enevoldsen, H 2015, ‘Marine harmful algal blooms, human health and wellbeing: challenges and opportunities in the 21st century’, *Journal of the Marine Biology Association of the United Kingdom*, vol. 96, pp. 61–91.

Berenzina, NA, Khlebovich, VV, Panov, VE & Zaporozhets, NV 2001, ‘Salinity Tolerance of the Amphipod *Gmelinoides fasciatus* (Stebb) Introduced into the Gulf of Finland Basin (the Baltic Sea)’, *Doklady Biological Sciences*, vol. 379, pp. 366–368.

Berenzina, NA, Zhakova, LV, Zaporozhets, NV & Panov, VE 2009, ‘Key role of the amphipod *Gmelinoides fasciatus* in reed beds of Lake Ladoga’, *Boreal Environment Research*, vol. 14, pp. 404–414.

Berger, MS, Darrah, AJ & Emlet, PB 2006, Spatial and temporal variability of early post-settlement survivorship and growth in the barnacle Balanus glandula along an estuarine gradient, *Journal of Experimental Marine Biology and Ecology*, vol. 336, no. 1, pp. 74–87.

Berry, PF 1978, ‘Reproduction, growth and production in the mussel, *Perna perna* (Linnaeus), on the east coast of South Africa’, *Investigational Report No. 48*, South African Association for Marine Biological Research, Oceanographic research institute, Durban.

Bertness, MD 1980, ‘Growth and mortality of the ribbed mussel *Geukensia demissa* (Bivalvia: Dreissenacea)’, *The Veliger*, vol. 23, pp. 62–69.

Beu, AG 2004, ‘Marine mollusca of oxygen isotope stages of the last 2 million years in New Zealand. Part 1: Revised generic positions and recognition of warm-water and cool-water migrants’, *Journal of the Royal Society of New Zealand*, vol. 34, pp. 111–265.

Bigatti, G, Miloslavich, P & Penchaszadeh, PER 2005, ‘Sexual differentiation and size at first maturity of the invasive mussel *Perna viridis* (Linnaeus, 1758) (Mollusca: Mytilidae) at La Restinga lagoon (Margarita Island, Venezuela)’, *American Malacological Bulletin*, vol. 20, pp. 65–69.

Bigatti, G, Signorelli, JH & Schwindt, E 2014, ‘Potential invasion of the Atlantic coast of South America by *Semimytilus algosus* (Gould, 1850)’, *BioInvasions Records*, vol. 3, no. 4, pp. 241–246.

Biosecurity New Zealand 2007, ‘Surveillance for early detection of unwanted marine organisms in New Zealand: Summer 2005–2006’, *MAF Biosecurity New Zealand Technical Paper No: 2007/02*, New Zealand.

Bishop, MWH 1951, ‘Distribution of barnacles by ships’, *Nature*, vol. 167, pp. 531.

Blair, D, Waycott, M, Byrne, L, Dunshea, G, Smith-Keune, C & Neil, KM 2006, ‘Molecular discrimination of Perna (Mollusca: Bivalvia) species using the polymerase chain reaction species-specific mitochondrial primers’, *Marine Biotechnology*, vol. 8, pp. 380–385.

Bogan, A 2012, ‘Limnoperna fortunei’, The IUCN Red List of Threatened Species 2012, e.T171818A1332873, accessed 15 May 2017.

Boos, K, Ashton, GV & Cook, EJ 2011, ‘The Japanese Skeleton Shrimp *Caprella mutica* (Crustacea, Amphipoda): A Global Invader of Coastal Waters’, in BS Galil, PF Clark & JT Carlton (eds), *In the Wrong Place—Alien Marine Crustaceans: Distribution, Biology and Impacts*, Springer Netherlands, Dordrecht, pp. 129.

Boschma, H 1930, ‘*Briarosaccus callosus*, a new genus and new species of a rhizocephalan parasite of *Lithodes agassizii* Smith’, *Proceedings of the United States National Museum*, vol. 76, pp. 1–8.

Bott, NJ & Giblot-Ducray, D 2011, *Molecular tools for detection of marine pests: Development of diagnostic PCR assays for the detection of significant marine pests: Carcinus maenas, Ciona intestinalis and Undaria pinnatifida*, report prepared for Adelaide & Mt Lofty Ranges Natural Resources Management Board, South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

Bott, NJ, Giblot-Ducray, D & Deveney, MR 2010, *Molecular tools for detection of marine pests: Development of putative diagnostic PCR assays for the detection of significant marine pests: Asterias amurensis, Carcinus maenas, Undaria pinnatifida and Ciona intestinalis*, South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

Bott, NJ, Giblot-Ducray, D & Sierp, M 2012, *Development of a qPCR assay for the Black-striped Mussel, Mytilopsis sallei*, South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

Boudreaux, ML & Walters, LJ 2006, '*Mytella charruana* (Bivalvia: Mytilidae): a new, invasive bivalve in Mosquito Lagoon, Florida', *The Nautilus*, vol. 120, pp. 34–36.

Bourgeois, M, Marx, J & Semon, K 2014, *Louisiana Blue Crab Fishery Management Plan*, Louisiana Department of Wildlife and Fisheries, Office of Fisheries.

Bownes, SJ & McQuaid CD 2006, 'Will the invasive mussel *Mytilus galloprovincialis* Lamarck replace the indigenous *Perna perna* L. on the south coast of South Africa?', *Journal of Experimental Marine Biology and Ecology*, vol. 338, pp. 140–151.

Boyle, T, Keith, D & Pfau, R 2010, 'Occurrence, reproduction and population genetics of the estuarine mud crab, *Rhithropanopeus Harrisii* (Gould) (Decapoda, Panopidae) in Texas freshwater reservoirs', *Crustaceana*, vol. 83, no. 4, pp. 493–505.

Bridgwood, S 2010, '*Codium fragile ssp. fragile* (Suringar) Hariot summary document', *Fisheries Research Report No. 202*, Department of Fisheries, Western Australia.

Bridgwood, S & McDonald, J 2014, 'A likelihood analysis of the introduction of marine pests to Western Australian ports via commercial vessels', *Fisheries Research Report No. 259*, Department of Fisheries, Western Australia.

Bridgwood, SD, Muñoz, J & McDonald, JI 2014, 'Catch me if you can! The story of a colonial ascidian's takeover bid in Western Australia', *BioInvasions Records*, vol. 3, pp. 217–223.

Briski, E, Ghabooli, S, Bailey, SA & MacIsaac, HJ 2012, 'Invasion risk posed by macroinvertebrates transported in ships' ballast tanks', *Biological Invasions*, vol. 14, pp. 1843–1850.

Brockerhoff, A, McLay, C 2011, 'Human-mediated spread of alien crabs', in GS Galil, PF Clark & JT Carlton (eds), *In the Wrong Place—Alien Marine Crustaceans: Distribution, Biology and Impacts*, Invading Nature 6, Springer, Dordrecht, Netherlands, pp. 27–106.

BRS 2009, CLIMATCH, Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry, Australian Government, Canberra, accessed 23 November 2016.

Bruce, BD & Green, MA 1998, The Spotted Handfish 1999–2001 Recovery Plan, Department of Environment and Energy, Canberra.

Burden, CT, Stow, AJ, Hoggard, SJ, Coleman, MA & Bishop, MJ 2014, 'Genetic structure of *Carcinus maenas* in southeast Australia', *Marine Ecology Progress Series*, vol. 500, pp. 139–147.

Buttermore, RE, Turner, E & Morrice, MG 1994, 'The introduced northern Pacific seastar *Asterias amurensis* in Tasmania', *Memoirs of the Queensland Museum*, vol. 36, pp. 21–25.

CABI 2012, 'Corbicula fluminea' (Asian clam) datasheet, Invasive Species Compendium, accessed May, 2017.

——2017a, 'Callinectes sapidus' (blue crab) datasheet, Invasive Species Compendium, accessed April 2017.

——2017b, 'Carijoa riisei' (branched pipe coral) datasheet, Invasive Species Compendium, accessed April 2017.

——2017c, 'Chthamalus proteus' datasheet, Invasive Species Compendium, accessed April 2017.

——2017d, 'Dreissena polymorpha' (zebra mussel) datasheet, Invasive Species Compendium, accessed April 2017.

——2017e, 'Hemigrapsus sanguineus' (Asian shore crab) datasheet, Invasive Species Compendium, accessed April 2017.

——2017f, 'Hemigrapsus takanoi' (brush-clawed shore crab) datasheet, Invasive Species Compendium, accessed April 2017.

——2017g, 'Limnoperna fortunei' (golden mussel) datasheet, Invasive Species Compendium, accessed April 2017.

——2017h, 'Perna viridis' (Asian green mussel) datasheet, Invasive Species Compendium, accessed April 2017.

——2017i, 'Styela clava' (Asian tunicate) datasheet, Invasive Species Compendium, accessed April 2017.

——2017j, 'Undaria pinnatifida' (Asian kelp) datasheet, Invasive Species Compendium, accessed April 2017.

Cardno 2015, Marine Pests Monitoring—Post-dredging report, prepared for INPEX Ichthys Nearshore Environmental Monitoring Program, INPEX, Darwin.

Carlton, JT 1979, 'History, Biogeography, and Ecology of the Introduced Marine and Estuarine Invertebrates of the Pacific Coast of North America', thesis, University of California, Davis, California, pp. 440–446.

Carlton, JT 1992, 'Introduced marine and estuarine mollusks of North America: an end-of-the 20th-century perspective', *Journal of Shellfish Research*, vol. 11, pp. 489–505.

Carlton, JT & Eldredge, LG 2015, 'Update and revisions of The Marine Bioinvasions of Hawai'i: the Introduced and Cryptogenic Marine and Estuarine Animals and Plants of the Hawaiian Archipelago', *Bishop Museum Bulletin in Zoology*, vol. 9, pp. 25–47.

Carlton, JT & Geller, JB 1993, 'Ecological roulette: the global transport of nonindigenous marine organisms', *Science*, vol. 261, pp. 78–82.

Carlton, JT, Thompson, JK, Schemel, LE & Nichols, FH 1990, 'Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam *Potamocorbula amurensis*. 1. Introduction and dispersal', *Marine Ecology Progress Series*, vol. 66, no.1–2, pp. 81–95.

Carnell, PE & Keough MJ 2014, 'Spatially variable synergistic effects of disturbance and additional nutrients on kelp recruitment and recovery', *Oecologia*, vol. 175, pp. 409–416.

Carranza, A & Borthagaray, A 2009, The brown mussel 'Perna perna' in the native mussel beds of Cerro Verde (Uruguay), *Marine Biodiversity Records*, vol. 2, no. 1.

Cartwright-Taylor, L, Von Bing, Y, Chia Chi, H & Sieu Tee, L 2011, 'Distribution and abundance of horseshoe crabs *Tachypleus gigas* and *Carcinoscorpius rotunicausa* around the main island of Singapore', *Aquatic Biology*, vol. 13, pp. 127–136.

Christie, A & Awal, S 2016, 'Invasive marine pests; the view from Point Cooke Marine Sanctuary', *The Victorian Naturalist*, vol. 133, no. 5, pp. 175–183.

CIESM 2006, *Callinectes sapidus*, CIESM: The Mediterranean Science Commission, August.

Çinar, ME 2016, 'The alien ascidian *Styela clava* now invading the Sea of Marmara (Tunicata: Ascidiacea)', *ZooKeys*, vol. 563, pp. 1–10.

Clark, PF, Rainbow, PS, Robbins, RS, Smith, B, Yeomans, WE, Thomas, M & Dobson, G 1998, 'The alien Chinese mitten crab, *Eriocheir sinensis* (Crusatcea: Decapoda: Brachyura), in the Thames Catchment', *Journal of the Marine Biological Association of the United Kingdom*, vol. 78, pp. 1215–1221.

Clarke, CL & Therriault, TW 2007, 'Biological synopsis of the invasive tunicate *Styela clava* (Herdman 1881)', *Canadian Manuscript Report of Fisheries and Aquatic Sciences 2807*, Department of Fisheries and Oceans, Canada.

Coan, EV & Valentisch-Scott, P 2012, *Bivalve Seashells of Tropical West America: Marine Bivalve Molluscks from Baja California to Northern Peru*, Santa Barbara Museum of Natural History, California, United States.

Coan, EV, Valentisch-Scott, P & Bernard, FR 2000, *Bivalve Seashells of Western North America: Marine Bivalve Mollusks from Arctic Alaska to Baja California*, Santa Barbara Museum of Natural History, California.

Coelho, CC, Zardi, GI, Pearson, GA, Serrao, EA & Nicastro, KR 2012, Characterization of ten highly polymorphic microsatellite loci for the intertidal mussel 'Perna perna', and cross species amplification within the genus, *BMC Research Notes*, vol. 5, pp. 558–562.

Cohen, AN 2009, *Managing the exotic mussels, 'Dreissena polymorpha', 'Dreissena bugensis', 'Limnoperna fortunei' and 'Mytilopsis leucophaeata' in SFPUC'S Reservoirs*, final report for the San Francisco Public Utilities Commission, San Francisco.

Cohen, AN 2011, The Exotics Guide: Non-native Marine Species of the North American Pacific Coast, Center for Research on Aquatic Bioinvasions: Richmond, California, and San Francisco Estuary Institute, Oakland, California, accessed 27 October 2016.

Cohen, AN & Carlton, JT 1998, 'Accelerating invasion rate in a highly invaded estuary', *Science*, vol. 279, pp. 555–558.

Coleman, N, Longmore, A & Cohen, B 2001, 'Baseline data for the Pinnace Channel Aquaculture Site', *Marine and Freshwater Resources Institute Report No. 34*, Marine and Freshwater Resources Institute, Queenscliff.

Coles, SL, DeFelice, RC, Eldredge, LG & Carlton, JT 1999, ‘Historical and recent introductions of non-indigenous marine species into Pearl Harbour, Oahu, Hawaiian Islands’, *Marine Biology*, vol. 135, pp. 147–158.

Corkum, LD, Sapoata, MR & Skora, KE 2004, ‘The round goby, *Neogobius melanostomus*, a fish invader on both sides of the Atlantic Ocean’, *Biological Invasions*, vol. 6, pp. 173–181.

Coutts, ADM 2006, *An evaluation of incursion response tools for invasive species: a case study of Didemnum vexillum in the Marlborough Sounds*, Cawthron Institute for Biosecurity New Zealand, Nelson.

Coutts ADM & Forrest BM 2005, *Evaluation of eradication tools for the clubbed tunicate ‘Styela clava’*, Cawthron Institute, Nelson.

Cragg, SM, Pitman, AJ & Henderson, SM 1999, ‘Developments in the understanding of the biology of marine wood boring crustaceans and in methods of controlling them’, *International Biodeterioration & Biodegradation*, vol. 43, pp. 197–205.

Cranfield, HJ, Gordon, DP, Willan, RC, Marshall, BA, Battershill, CN, Francis, MP, Nelson, WA, Glasby, CJ & Read GB 1998, *Adventive marine species in New Zealand*, National Institute of Water and Atmospheric Research, Wellington, New Zealand.

Critchley, AT, Farnham, WF & Morrell, SL 1986, ‘An account of the attempted control of an introduced marine alga, *Sargassum muticum*, in southern England’, *Biological Conservation*, vol. 35, pp. 313–332.

Crooks, JA 1996, ‘The population ecology of an exotic mussel, *Musculista senhousia*, in a southern California Bay’, *Estuaries*, vol. 19, pp. 42–50.

CRUSTA 2012, Species from French Polynesia, CRUSTA database, accessed 24 November 2016.

Csurhes, S 2015, *Invasive Species Risk Assessment—Asian green mussel ‘Perna viridis’*, draft report to Biosecurity Queensland, Queensland.

Dall, WH, Bartsch, P & Rehder, HA 1938, ‘A Manual of the Recent and Fossil Marine Pelecypod Mollusks of the Hawaiian Islands’, *Bernice P Bishop Museum, Honolulu, Bulletin*, vol. 153, pp. 1–233.

D’Archino, R, Nelson, WA & Zuccarello, GC 2007, ‘Invasive marine red alga introduced to New Zealand waters: first record of *Grateloupia turuturu* (Halymeniales, Rhodophyta)’, *New Zealand Journal of Marine and Freshwater Research*, vol. 41, pp. 35–42.

D’Archino, R & Zuccarello, GC 2014, ‘First record of *Schizymenia apoda* (Schizymeniaceae, Rhodophyta) in New Zealand’, *New Zealand Journal of Marine Freshwater Research*, vol. 48, pp. 155–162.

Darr, A & Zettler, ML 2000, ‘Erstnachweis von Congeria leucophaeata (Conrad, 1831) in Mecklenburg-Vorpommern (Bivalvia: Dreissenidae)’, *Malakologische Abhteing*, vol. 20, pp. 197–200.

Dartnall, AJ 1969, ‘New Zealand sea stars in Tasmania’, *Papers and Proceedings of the Royal Society of Tasmania*, vol. 103, pp. 53–55.

Dauvin, JC, Rius, AT & Ruellet, T 2009, 'Recent expansion of two invasive crabs species *Hemigrapsus sanguineus* (de Haan, 1835) and *H. takanoi* (Asakura and Watanabe, 2005) along the Opal Coast, France', *Aquatic Invasions*, vol. 4, no. 3, pp. 451–465.

Davis, MH & Davis, ME 2007, 'The distribution of *Styela clava* (Tunicata, Ascidiacea) in European waters', *Journal of Experimental Marine Biology and Ecology*, vol. 342, pp. 182–184.

de Barros, R, da Rocha, RM, & Pie, MR 2009, 'Human-mediated global dispersion of *Styela plicata* (Tunicata, Ascidiacea)', *Aquatic Invasions*, vol. 4, pp. 45–57.

de Greef, K, Griffiths, CL & Zeeman, Z 2013, 'Déjà vu? A second mytilid mussel, *Semimytilus algosus*, invades South Africa's west coast', *African Journal of Marine Science*, vol. 35, pp. 307–313.

Deagle, BE, Bax, N, Hewitt, CL & Patil, JG 2003, 'Development and evaluation of a PCR-based test for detection of *Asterias* (Echinodermata: Asteroidea) larvae in Australian plankton samples from ballast water', *Marine and Freshwater Research*, vol. 54, pp. 709–719.

Denny, CM 2008, 'Development of a method to reduce the spread of the ascidian *Didemnum vexillum* with aquaculture transfers', *ICES Journal of Marine Science*, vol. 65, pp. 805–810.

Department of Agriculture and Water Resources 2010, Australian marine pest monitoring manual, Department of Agriculture and Water Resources, Canberra.

——2015a, Review of national marine pest biosecurity: report, Department of Agriculture and Water Resources for the National System for the Prevention and Management of Marine Pest Incursions, Canberra.

——2015b, Black striped mussel ('Mytilopsis sallei') and Asian green mussel ('Perna viridis')—Australian Emergency Marine Pest Plan (EMPPlan) Rapid Response Manual, Department of Agriculture and Water Resources for the National System for the Prevention and Management of Marine Pest Incursions, Canberra.

——2015c, European green crab ('Carcinus maenas')—Australian Emergency Marine Pest Plan (EMPPlan) Rapid Response Manual, Department of Agriculture and Water Resources for the National System for the Prevention and Management of Marine Pest Incursions, Canberra.

——2015d, Japanese seaweed ('Undaria pinnatifida')—Australian Emergency Marine Pest Plan (EMPPlan) Rapid Response Manual, Department of Agriculture and Water Resources for the National System for the Prevention and Management of Marine Pest Incursions, Canberra.

——2015e, Northern Pacific sea star ('Asterias amurensis')—Australian Emergency Marine Pest Plan (EMPPlan) Rapid response manual, Department of Agriculture and Water Resources for the National System for the Prevention and Management of Marine Pest Incursions, Canberra.

deRivera, C, Hitchcock, N, Teck, S, Steves, B, Hines, AH & Ruiz, G 2007, 'Larval development rate predicts range expansion of an introduced crab', *Marine Biology*, vol. 150, pp. 1275–1288.

Dias, J, Fotedar, S, Munoz, J, Hewitt, MJ, Lukehurst, S, Hourston, M, Wellington, C, Duggan, R, Bridgwood, S, Massam, M, Aitken, V, de Lestang, P, McKirdy, S, Willan, RC, Kirkendale, L, Giannetta, J, Corsini-Foka, M, Pothoven, S, Gower, F, Viard, F, Buschbaum, C, Scarcella, G, Strafella, P, Bishop, MJ, Sullivan, T, Buttino, I, Madduppa, H, Huhn, M, Zabin, CJ, Bacela-Spychalska, K, Wójcik-Fudalewska, D, Markert, A, Maximov, A, Kautsky, L, Jaspers, C, Kotta, J, Parnoja, M, Robledo, D, Tsiamis, K, Küpper, FC, Žuljević, A, McDonald, JI & Snow, M 2017, 'Establishment of a taxonomic and molecular reference collection to support the identification of species regulated by the Western Australian Prevention List for Introduced Marine Pests', *Management of Biological Invasions*, vol. 8, no. 2, pp. 215–225.

Dias, PJ, Rocha, R, Godwin, S, Tovar-Hernandez, MA, Delahoz, MV, McKirdy, S, de Lestang, P, McDonald, JI & Snow, M 2016, 'Investigating the cryptogenic status of the sea squirt *Didemnum perlucidum* (Tunicata, Ascidiacea) in Australia based on a molecular study of its global distribution', *Aquatic Invasions*, vol. 11, pp. 239–245.

Dimond, PE, Mandrak, NE & Brownsen, B 2010, *Summary of the rapid response to Round Goby (Neogobius melanostomus) in Pefferlaw Brook with an evaluation of the national rapid response framework based on the Pefferlaw Brook experience*, Department of Fisheries and Oceans, Canadian Science Advisory Secretariat research document 2010/036, Canada.

Dodgshun, T, Taylor, MD & Forrest, BM 2007, *Human-mediated pathways of spread for non-indigenous marine species in New Zealand*, Department of Conservation New Zealand, New Zealand.

Dowell, K 2011, '*Rhithropanopeus harrisii*, Estuarine mud crab or Harris mud crab', *Fish 423*, University of Washington, New Zealand.

DPIPWE 2015, Undaria (Wakame) Action Plan, Department of Primary Industries, Parks, Water and Environment, Tasmanian Government, Hobart, accessed April 2017.

——2017, Northern Pacific Seastar ('Asterias Amurensis'), Department of Primary Industries, Parks, Water and Environment, Tasmania, accessed 29 March 2017.

Dunstan, PK & Bax, NJ 2007, 'How far can marine species go? Influence of population biology and larval movement on future range limits', *Marine Ecology Progress Series*, vol. 344, pp. 15–28.

Eldridge, LG & Smith, CM 2001, 'A guidebook of introduced marine species in Hawaii', *Bishop Museum Technical Report 21*, Hawaii.

Engle, J, Miller, KA & Alstatt, J n.d., 'Sargassum' identification guide, University of California Santa Cruz—Ecology and Evolutionary Biology.

Epe, S 2012, *European Green Shore Crab 'Carcinus maenas': information sheet for NSW Oyster Farmers*, Sapphire Coast Marine Discovery Centre, Caring for our Country Project, Eden, New South Wales.

Epifanio, CE 2013, 'Invasion biology of the Asian shore crab *Hemigrapsus sanguineus*: A review', *Journal of Experimental Marine Biology and Ecology*, vol. 441, pp. 33–49.

Fajans, JS & Baker, P 2003, 'Tracking the spread of an invasive mussel (Mytilidae: *Perna viridis*) in Florida', *Journal of Shellfish Research*, vol. 22, pp. 329.

Farnham, WF, Jones, EBG 1974, 'The eradication of the seaweed *Sargassum muticum* from Britain', *Biological Conservation*, vol. 6, no. 1, pp. 57–58.

Fishbase n.d., *Siganus rivulatus*, accessed 24 November 2016.

Fitridge, I, Dempster, T, Guenther, J & de Nys, R 2012, 'The impact and control of biofouling in marine aquaculture: a review', *Biofouling: The Journal of Bioadhesion and Biofilm Research*, vol. 28, pp. 649–669.

Fletcher, LM, Forrest, BM & Bell, JJ 2013, 'Natural dispersal mechanisms and dispersal potential of the invasive ascidian *Didemnum vexillum*', *Biological Invasions*, vol. 15, pp. 627–643.

Florin, AB, Mo, K, Svensson, F, Schagerstrom, E, Kautsky, L & Bergstrom, L 2013, 'First records of Conrad's false mussel, *Mytilopsis leucophaeata* (Conrad, 1831) in the southern Bothnian Sea, Sweden, near a nuclear power plant', *BioInvasions Records*, vol. 2, pp. 303–309.

Fofonoff, PW, Ruiz, GM, Steves B, Simkanin, C, & Carlton JT 2017, National Exotic Marine and Estuarine Species Information System, Smithsonian Environmental Research Center, accessed 15 May 2017.

Fofonoff, PW, Ruiz, GM, Steves, B & Carlton, JT 2003, California Non-native Estuarine and Marine Organisms (Cal-NEMO) System, Smithsonian Environmental Research Center, accessed 20 April 2017.

Forrest, BM, Fletcher, LM, Atalah, J, Piola, RF & Hopkins, GA 2013, 'Predation limits spread of *Didemnum vexillum* into natural habitats from refuges on anthropogenic structures', *PLoS ONE*, vol. 8, e82229.

Forrest, BM, Gardner, JPA & Taylor, MD 2009, 'Internal borders for managing invasive marine species', *Journal of Applied Ecology*, vol. 46, pp. 46–54.

Forrest, BM & Hopkins, GA 2013, 'Population control to mitigate the spread of marine pests: insights from management of the Asian kelp *Undaria pinnatifida* and colonial ascidian *Didemnum vexillum*', *Management of Biological Invasions*, vol. 4, pp. 317–326.

Forrest, BM, Hopkins, GA, Dodgshun, TJ, & Gardner, JPA 2007, 'Efficacy of acetic acid treatments in the management of marine biofouling', *Aquaculture*, vol. 262, pp. 319–332.

Forsstrom, T, Fowler, AE, Lindqvist, M & Vesakoski, O 2016, 'The introduced dark false mussel, *Mytilopsis leucophaeata* (Conrad, 1831) has spread in the northern Baltic Sea', *BioInvasions Records*, vol. 5, pp. 81–84.

Forsstrom, T, Fowler AE, Manninen, I & Vesakoski, O 2015, 'An introduced species meets the local fauna: predatory behaviour of the crab *Rhithropanopeus harrisii* in the northern Baltic Sea', *Biological Invasions*, vol. 17, pp. 2729–2741.

Fowler, AE, Forrström, T, von Numers, M & Vesakoski, O 2013, 'The North American mud crab *Rhithropanopeus harrisii* (Gould, 1841) in newly colonized Northern Baltic Sea: distribution and ecology', *Aquatic Invasions*, vol. 8, no. 1, pp. 89–96.

Fowler, AE & McLay, CL 2013, 'Early stages of a New Zealand invasion by *Charybdis japonica* (Milne-Edwards, 1861) (Brachyura: Portunidae) from Asia: population demography', *Journal of Crustacean Biology*, vol. 33, pp. 224–234.

Fowler, AE, Gerner, NV & Sewell, MA 2011, 'Temperature and salinity tolerances of Stage 1 zoeae predict possible range expansion of an introduced portunid crab, *Charybdis japonica*, in New Zealand', *Biological Invasions*, vol. 13, pp. 691–699.

Fricke, R 2010, 'Siganus rivulatus', the IUCN Red List of Threatened Species, accessed 15 March 2017.

Fulton, SW, Grant, FE 1900, 'Note on the occurrence of the European crab, *Carcinus maenas* Leach, in Port Phillip Bay', *Victorian Naturalist*, vol. 17, pp. 145–146.

Furlani, D 1996, *A Guide to the Introduced Marine Species in Australian Waters*, CSIRO, Hobart, Tasmania.

Gagnom K & Bostrom, C 2016, 'Habitat expansion of the Harris mud crab *Rhithropanopeus harrisii* (Gould, 1841) in the northern Baltic Sea: potential consequences for the eelgrass foodweb', *Bioinvasion Records*, vol. 5, no. 2, pp. 101–106.

Galil, BS 2002, 'Control and eradication of invasive aquatic invertebrates', in F Gherardi, C Corti, M Gualtieri (eds), Biodiversity conservation and habitat management. *The Encyclopaedia of Life Support Systems*, EOLSS Publishers, Oxford, UK/UNESCO, pp. 1–14.

Galil, BS 2006a, 'Musculista senhousia', Delivering Alien Invasive Species Inventories for Europe (DAISIE), accessed 27 October 2016.

——2006b, 'Siganus rivulatus', Delivering Alien Invasive Species Inventories for Europe (DAISIE), accessed 24 November 2016.

Galil, BS & Bogi, C 2009, '*Mytilopsis sallei* (Mollusca: Bivalvia: Dreissenidae) established on the Mediterranean coast of Israel', *Marine Biodiversity Records*, vol. 2.

Garbary, DJ, Miller, AG, Williams, JD, Seymour, NR 2014, 'Drastic decline of an extensive eelgrass bed in Nova Scotia due to the activity of the invasive green crab (*Carcinus maenas*)', *Marine Biology*, vol. 161, pp. 3–15.

Garcia-Jiminez, P, Geraldino, PJL, Boo, SM & Robaino, RR 2008, 'Red algae *Grateloupia imbricata* (Halymeniaceae), a species introduced into the Canary Islands', *Phycological Research*, vol. 56, pp. 166–171.

Garside, CJ, Glasby, TM, Coleman, MA, Kelaher, BP & Bishop, MJ 2014, 'The frequency of connection of coastal water bodies to the ocean predicts *Carcinus maenas* invasion', *Limnology and Oceanography*, vol. 59, pp. 1288–1296.

Geburzi, JC, Graumann, G, Köhnk, S & Brandis, D 2015, 'First record of the Asian crab *Hemigrapsus takanoi* Asakura & Watanabe, 2005 (Decapoda, Brachyura, Varunidae) in the Baltic Sea', *BioInvasions Records*, vol. 4, pp. 103–107.

Geller, J, Sotka, EE, Kado, R, Palumbi, SR & Schwindt, E 2008, 'Sources of invasions of a north-eastern Pacific acorn barnacle, *Balanus glandula*, in Japan and Argentina', *Marine Ecology Progress Series*, vol. 358, pp. 211–218.

Gilg, MR, Hoffman, EA, Schneider, KR, Ryabinove, J, El-Khoury, C & Walters, LJ 2010, 'Recruitment preferences of non-native mussels, interaction between marine invasions and land-use changes', *Journal of Molluscan Studies*, vol. 76, pp. 333–339.

GISD 2017a, Species profile: 'Asterias amurensis', Global Invasive Species Database, Invasive Species Specialist Group, accessed 29 March 2017.

——2017b, Species profile: 'Corbicula fluminea', Global Invasive Species Database, Invasive Species Specialist Group, accessed April 2017.

——2017c, Species profile: 'Dreissena bugensis', Global Invasive Species Database, Invasive Species Specialist Group, accessed April 2017.

——2017d, Species profile: 'Dreissena polymorpha', Global Invasive Species Database, Invasive Species Specialist Group, accessed April 2017.

——2017e, Species profile: 'Gracilaria vermiculophylla', Global Invasive Species Database, Invasive Species Specialist Group, accessed 11 April 2017.

——2017f, Species profile: 'Limnoperna fortunei', Global Invasive Species Database, Invasive Species Specialist Group, accessed April 2017.

——2017g, Species profile: 'Mytilopsis leucophaeata', Global Invasive Species Database, Invasive Species Specialist Group, accessed 11 April 2017.

——2017h, Species profile: 'Potamocorbula amurensis', Global Invasive Species Database, Invasive Species Specialist Group, accessed 27 October 2016.

——2017i, Species profile: 'Perna perna', Global Invasive Species Database, Invasive Species Specialist Group, accessed 12 April 2017.

——2017j, Species profile: 'Perna viridis', Global Invasive Species Database, Invasive Species Specialist Group, accessed 12 April 2017.

——2017k, Species profile: 'Rapana venosa', Global Invasive Species Database, accessed April 2017.

——2017l, Species profile: 'Rhithropanopeus harrisii', Global Invasive Species Database, accessed 9 May 2017.

——2017m, Species profile: 'Styela clava', Global Invasive Species Database, Invasive Species Specialist Group, accessed 20 April 2017.

——2017n, Species profile: 'Watersipora subtorquata', Global Invasive Species Database, Invasive Species Specialist Group, accessed 20 April 2017.

Gittenberger, A 2010, *Risk analysis of the colonial sea-squirt Didemnum vexillum Kott, 2002 in the Dutch Wadden Sea, a UNESCO World Heritage Site*, GiMaRIS, report for the Dutch Ministry of Agriculture, Nature and Food Quality, Netherlands.

Glasby, TM & Lobb, K 2008, 'Assessing the likelihood of marine pest introductions in Sydney estuaries: a transport vector approach', *NSW DPI Fisheries Final Report Series No. 105*, report for

Sydney Metropolitan Catchment Management Authority, NSW Department of Primary Industries, Sydney.

Gloer, P & Zettler, ML 2005, 'Kommentierte Artenliste ser Susswatermollusken Deutschlands', *Malakologische Abhteing*, vol. 23, pp. 3–22.

Golder Associates Ltd 2008, 'Trial of a control programme for non-indigenous crustaceans using Charybdis japonica' as a case study, *Biosecurity New Zealand Technical Paper No: 2009/03*, prepared for Biosecurity New Zealand Post-Clearance Directorate, Ministry of Agriculture and Forestry, New Zealand.

Goldstien, SJ, Dupont, L, Viard, F, Hallas, PJ, Nishikawa, T, Schiel, DR, Gemmell, NJ, Bishop, JDD 2011, 'Global Phylogeography of the Widely Introduced North West Pacific Ascidian *Styela clava*', *PLoS ONE*, vol. 6, no. 2, e16755.

Gollasch, S 1999, 'The Asian decapod *Hemigrapsus penicillatus* (de Haan, 1835) (Grapsidae, Decapoda) introduced in European waters: status quo and future perspective', *Helgoländer Meeresuntersuchungen*, vol. 52, pp. 359–366.

——2006, 'Overview on introduced aquatic species in European navigational and adjacent waters', *Helgoland Marine Research*, vol. 60, no. 2, pp. 84–89.

——2011, NOBANIS—Invasive Alien Species Fact Sheet 'Eriocheir sinensis', online database of the European Network on Invasive Alien Species, NOBANIS, accessed April 2017.

Gordon, DP & Mawatari, SF 1992, 'Atlas of marine-fouling bryozoa of New Zealand ports and harbours', miscellaneous publication *New Zealand Oceanographic Institute*, vol. 107, pp. 1–52.

Gribben, PE, I'Ons, S, Phillips, NE, Geange, SW, Wright, JT, Murray, BR 2013, 'Biogeographic comparisons of the morphology, biomass and abundance of an invasive crab throughout its native and invasive ranges', *Biological Invasions*, vol. 15, pp. 1877–1885.

Gribben, PE, Jeffs, AG, de Nys, R & Steinberg, PD 2011, 'Relative importance of natural cues and substrate morphology for settlement of the New Zealand Greenshell mussel, *Perna canaliculus',* *Aquaculture*, vol. 319, pp. 240–246.

Gribben, PE, Simpson, M, Wright, JT 2015, 'Variable habitat availability and invasion as drivers of biogeographic patterns of intertidal community structure', *Marine Environmental Research*, vol. 110, pp. 124–131.

Griffiths, C, Robinson, T & Mead, A 2011, 'The alien and cryptogenic marine crustaceans in South Africa', in BS Galil, PF Clark & JT Carlton (eds), *In the Wrong Place: Alien Marine Crustaceans: Distribution, Biology and Impacts*, Springer, Dordrecht, pp. 269–282.

Gruet, Y, Vimpère, J, Sauriau, PG & Le Roux, A 2014, 'La balane *Hesperibalanus fallax* (Broch, 1927) (Crustacé Cirripède) sur la côte Francaise Atlantique du Golfe de Gascogne et sa présence en baie de Seine (Manche orientale) dès 1976', *Bulletin du Societe des Sciences Naturales Ouest de la France, nouvelle serie*, vol. 36, no. 4, pp. 244–256.

Guiry, MD 2015, 'Grateloupia imbricata' Holmes, 1896, in Guiry, MD & Guiry, GM 2017, AlgaeBase, National University of Ireland, Galway, accessed 12 April 2017.

——2017a, 'Codium fragile subsp. fragile' (Suringar) Hariot, in MD Guiry & GM Guiry, AlgaeBase, National University of Ireland, Galway, accessed 13 April 2017.

——2017b, 'Gracilaria vermiculophylla' (Ohmi) Papenfuss, 1967, in Guiry, MD & Guiry, GM 2017, AlgaeBase, National University of Ireland, Galway, accessed 12 April 2017.

——2017c, 'Sargassum horneri' (Turner) C. Agardh, in Guiry, MD & Guiry, GM 2017, AlgaeBase, National University of Ireland, Galway, accessed 13 April 2017.

——2017d, 'Sargassum muticum' (Yendo) Fensholt, in Guiry, MD & Guiry, GM 2017, AlgaeBase, National University of Ireland, Galway, accessed 13 April 2017.

——2017e, 'Schizymenia apoda' (J. Agardh) J. Agardh, in Guiry, MD & Guiry, GM 2017, AlgaeBase, National University of Ireland, Galway, accessed 26 April 2017.

——2017f, 'Undaria pinnatifida' (Harvey) Suringar, in Guiry, M & Guiry, GM 2017, AlgaeBase, National University of Ireland, Galway, accessed 13 April 2017.

——2017g, 'Grateloupia turuturu', in MD Guiry & GM Guiry (eds), AlgaeBase, National University of Ireland, Galway, accessed 27 April 2017.

Gulf States Fisheries Commission 2005, *Non-native Aquatic Species Summaries: Perna perna*, Gulf States Fisheries Commission, United States.

Gust, N & Inglis, GJ 2006, 'Adaptive multi-scale sampling to determine an invasive crab's habitat usage and range in New Zealand', *Biological Invasions*, vol. 8, pp. 339–353.

Hatanaka, M & Kosaka, M 1959, 'Biological studies on the population of the starfish, 'Asterias amurensis', in Sendai Bay', *Tohoku Journal of Agricultural Research*, vol. 9, no. 3, pp. 159–178.

Hayes, KR, Migus, S, Sliwa, C, McEnnulty, F & Barry S 2004, *Ballast water decision support system (DSS) service level agreement (SLA)—part II*, CSIRO Division of Marine and Atmospheric Research, Hobart.

Hayes, KR, Sliwa, C 2003, 'Identifying potential marine pests—a deductive approach applied to Australia', *Marine Pollution Bulletin*, vol. 46, pp. 91–98.

Hayes, KR, Sliwa, C, Migus, S, McEnnulty, F & Dunstan, P 2005, *National priority pests. Part II, ranking of Australian marine pests*, report to the Department of the Environment and Energy, Canberra.

He, J, Qi, JF, Qing Feng, D, Ke, CH 2016, 'Embryonic and larval development of the invasive biofouler *Mytilopsis sallei* (Récluz, 1849) (Bivalvia: Dreissenidae)', *Journal of Molluscan Studies*, vol. 82, pp. 23–30.

Hegele-Drywa, J & Normant, M 2014, 'Non-native crab *Rhithropanopeus harrisii* (Gould 1984)—a new component of the benthic communities in the Gulf of Gdansk (southern Baltic Sea)', *Oceanologia*, vol. 56, no. 1, pp. 125–139.

Herboug, LM, O'Hara, P & Therriault, TW 2009, 'Forecasting the potential distribution of the invasive tunicate *Didemnum vexillum*', *Journal of Applied Ecology*, vol. 46, pp. 64–72.

Hewitt, C, Campbell, M, Coutts, A, Dahlstrom, A, Shields, D & Valentine, J 2011, *Species Biofouling Risk Assessment*, report for the Department of Agriculture and Water Resources, Canberra.

Hickman, RW, Illingworth, J, Meredyth-Young, JL & Payne, G 1991, 'The relationship between farmed mussels *Perna canaliculus* and available food in Pelorous-Kenepuru Sound, New Zealand, 1983–1985', *Aquaculture*, vol. 99, pp. 49–68.

Hicks, DW & Tunnel, JW 1995, 'Ecological notes and patterns of dispersal in the recently introduced mussel, *Perna perna* (Linnaeus 1758), in the Gulf of Mexico', *American Malacological Bulletin*, vol. 11, pp. 203–206.

Hill, K 2004, Callinectes sapidus (blue crab), Smithsonian Marine Station at Fort Pierce.

Hirst, A & Bott, NJ 2016, *Marine Pests in the Gippsland lakes: Existing Threats and Future Monitoring*, Centre for Environmental Sustainability and Remediation, RMIT University, Melbourne.

Hopkins, GA, Forrest, BM, Jiang, W & Gardner, JPA 2011, 'Successful eradication of a non-indigenous marine bivalve from a soft sediment environment', *Journal of Animal Ecology*, vol. 48, no. 2, pp. 424–431.

Hosie, AM 2008, Hesperibalanus fallax' A barnacle, in H Tyler-Walters & K Hiscock (eds), *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, Marine Biological Association of the United Kingdom, Plymouth, England, accessed 28 October 2016.

Hosie A & Ayhong ST 2008, 'First records of the giant barnacles, *Austromegabalanus nigrescens* (Lamarck, 1818) and *A. psittacus* (Molina, 1782) (Cirripedia: Balanidae) from New Zealand, with a key to New Zealand Balanidae', *Zootaxa*, vol. 1674, pp. 59–64.

'Hourston, M, McDonald, JI & Hewitt, MJ 2015, 'Public engagement for the detection of the introduced marine species *Charybdis japonica* in Western Australia', *Management of Biological Invasions*, vol. 6, pp. 243–252.

Huber, M 2010, *Compendium of Bivalves*, Conchbooks, Hackenheim, Germany.

Huisman JM, Jones DS, Wells FE & Burton, T 2008, 'Introduced marine biota in Western Australian waters', *Records of the Western Australian Museum*, vol. 25, pp. 1–44.

IMO 2004, International convention for the control and management of ships' ballast water and sediments (BWM), International Maritime Organization, London.

——2011, 2011 guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species: resolution MEPC.207(62), International Maritime Organization, London.

——2012, Guidance for minimizing the transfer of invasive aquatic species as biofouling (hull fouling) for recreational craft: MEPC.1/Circ.792, International Maritime Organization, London.

Inglis, GJ, Floerl, O, Ahyong, S, Cox, S, Unwin, M, Ponder-Sutton, A, Seaward, K, Kospartov, M, Read, G, Gordon, D, Hosie, A, Nelson, W, d'Archino, R, Bell & A, Kluza, D 2010, 'The biosecurity risks associated with biofouling on international vessels arriving in New Zealand: summary of the patterns and predictors of fouling', *Biosecurity New Zealand Technical Paper No: 2008*, report for the Ministry of Primary Industries, New Zealand.

IUCN 2000, *Guidelines for the Prevention of Biodiversity Loss due to Biological Invasion, International union for conservation of nature*, Gland, Switzerland.

James, K & Shears NT 2016a, 'Proliferation of the invasive kelp *Undaria pinnatifida* at aquaculture sites promotes spread to coastal reefs', *Marine Biology*, vol. 163, no. 2, pp. 1–12.

——2016b, 'Population ecology of the invasive kelp *Undaria pinnatifida* towards the upper extreme of its temperature range', *Marine Biology*, vol. 163, no. 11, pp. 1–14.

Jeffs, AG, Holland, RC, Hooker, SH & Hayden, BJ 1999, 'Overview and bibliography of research on the greenshell mussel, *Perna canaliculus*, from New Zealand waters', *Journal of Shellfish Research*, vol. 18, pp. 347–360.

Jensen, KR 2010a, NOBANIS—Invasive Alien Species Fact Sheet—Callinectes sapidus, NOBANIS, European Network on Invasive Alien Species.

——2010b, NOBANIS—Invasive Alien Species Fact Sheet—Caprella mutica, NOBANIS, European Network on Invasive Alien Species.

Josefsson, M & Jansson, K 2011, NOBANIS—Invasive Alien Species Fact Sheet—Sargassum muticum, NOBANIS, European Network on Invasive Alien Species.

Kado, R 2003, 'Invasion of Japanese shores by the NE Pacific barnacle *Balanus glandula* and its ecological and biogeographical impact', *Marine Ecology Progress Series*, vol. 249, pp. 199–206.

Kalchhauser, I, Mutzner, P, Hirsch, P. & Burkhardt-Holm, P 2013, 'Arrival of round goby *Neogobius melanostomus* (Pallas, 1814) and bighead goby *Ponticola kessleri* (Gunther, 1861) in the High Rhine (Switzerland)', *BioInvasions Records*, vol. 2, pp. 79–83.

Karsiotis, SI, Pierce, LR, Brown, JE & Stepien, CA 2012, 'Salinity tolerance of the invasive round goby: Experimental implications for seawater ballast exchange and spread to North American estuaries', *Journal of Great Lakes Research*, vol. 38, pp. 121–128.

Kashenko, SD 1996, 'Effects of desalination on the larval settlement and metamorphosis of the ascidian *Styela clava*', *Biologiya Morya, Vladivostok*, vol. 2, pp. 174–178.

Katsanevakis, S, Wallentinus, I, Zenotos, A, Leppakoski, E, Cinar, ME, Ozturk, B, Grabowski, M, Golani, D & Cardosa, AC 2014, 'Impacts of invasive alien marine on ecosystem services and biodiversity: a pan-European review', *Aquatic Invasions*, vol. 9, no. 4, pp. 391–423.

Kay, EA 1979, *Hawaiian Marine Shells, Reef and Shore fauna of Hawaii, Section 4: Mollusca*, Bernice P. Bishop Museum Press, Honolulu.

Keen, AM 1971, Sea Shells of Tropical West America. Marine Mollusks from Baja California to Peru, Second edition, Stanford University Press, Palo Alto, California.

Keith, D 2000, Occurrence of the Estuarine Mud Crab, Rhithropanopeus harrisii, in Texas Reservoirs, Tarleton State University, Texas, accessed 24 November 2016.

Kennedy, VS 2011, 'The invasive dark false mussel *Mytilopsis leucophaeata* (Bivalvia: Dreissenidae): a literature review', *Aquatic Ecology*, vol. 45, pp. 163–183.

Kensley, B & Penrith, M 1970, 'New records of Mytilidae from the northern South West African coast', *Annals of the South African Museum*, vol. 57, pp. 15–20.

Keough, MJ & Chernoff, H 1987, 'Dispersal and population variation in the Bryozoan *Bugula neritina*', *Ecology*, vol. 68, pp. 199–210.

Keough, MJ & Ross, DJ 1999, 'Introduced fouling species in Port Phillip Bay', in CL Hewitt, ML Campbell, RE Thresher & Martin, RB (eds), *Marine Biological invasions of Port Phillip Bay*, *Victoria*, CSIRO Marine Research, Hobart, pp. 193–226.

Kim, SY, Weinberger, F & Boo, SM 2010, 'Genetic data hint at common donor region for invasive Atlantic and Pacific populations of *Gracilaria vermiculophylla* (Gracilariales, Rhodophyta)', *Journal of Phycology*, vol. 46, pp. 1346–1349.

King, R 1997, 'Systematic relationships between Tasmanian and New Zealand populations of *Petrolisthes elongatus* (Crustacea: Anomura: Porcellanidea)', thesis, University of Melbourne, Victoria.

Kott P 1990, 'The Australian Ascidiacea II. Aplousobranchia', *Memoirs of the Queensland Museum*, vol. 29, pp. 1–266.

——1985, 'The Australian Ascidiacea. Part I. Phlebobranchia and Stolidobranchia', *Memoirs of the Queensland Museum*, vol. 23, pp. 1–440.

——2002, 'A complex didemnid ascidian from Whanga-mata, New Zealand', *Journal of the Marine Biological Association of the United Kingdom*, vol. 82, pp. 625–628.

——2004, A new species of *Didemnum* (Ascidiacea, Tunicata) from the Atlantic coast of North America, *Zootaxa*, vol. 732, pp. 1–10.

Laine, AO, Mattila, J & Lehikoinen, A 2006, 'First record of the brackish water dreissenid bivalve *Mytilopsis leucophaeata* in the northern Baltic Sea', *Aquatic Invasions*, vol. 1, pp. 38–41.

Lambert, G 2002, 'Nonindigenous Ascidians in Tropical Waters', *Pacific Science*, vol. 56, pp. 291–298.

Lambert, G 2009, 'Adventures of a sea squirt sleuth: unravelling the identity of *Didemnum vexillum*, a global ascidian invader', *Aquatic Invasions*, vol. 1, pp. 5–28.

Laursen, D 1966, 'The genus *Mya* in the Arctic region', *Malacologia*, vol. 3, pp. 399–418.

Lee, HG 1987, 'Immigrant mussel settles in North side generator', *The Shell-O-Gram,* Jacksonville Shell Club, Jacksonville, Florida, vol. 28, pp. 7–9.

Leppäkoski, EJ 1991, 'Introduced species—resource or threat in brackish-water seas? Examples from the Baltic and Black seas', *Marine Pollution Bulletin*, vol. 23, pp. 219–223.

Lin, G & Yang, Q 2006, 'Impacts of alien species *Mytilopsis sallei* on phytoplankton at Muluan Bay in Xiamen, Fujian, China', *Journal of Tropical Oceanography*, vol. 25, pp. 63–67.

Ling, SD 2000, 'The effect of anthropogenic structures on reproductive output of the northern Pacific seastar *Asterias amurensis* in the Derwent River estuary', thesis, University of Tasmania, Hobart.

Ling, SD, Johnson, CR, Mundy, CN, Morris, A & Ross, DJ 2012, 'Hotspots of exotic free-spawning sex: man-made environment facilitates success of an invasive seastar', *Journal of Applied Ecology*, vol. 49, pp. 733–741.

Lockhart, SJ & Ritz, DA 2001, 'Preliminary observations of the feeding periodicity and selectivity of the introduced seastar, *Asterias amurensis* (Ltitken), in Tasmania, Australia', *Papers and Proceedings of the Royal Society of Tasmania*, vol. 135, pp. 25–33.

Lokko, K, Kotta, J, Orav-Kotta, H, Nurkse, K & Pärnoja, M 2015, 'Introduction of a functionally novel consumer to a low diversity system: Effects of the mud crab *Rhithropanopeus harrisii* on meiobenthos', *Estuarine, Coastal and Shelf Science*, vol. 201, pp. 132–139.

Lovell, S, Besedin, E & Grosholz, E 2007, 'Modeling economic impacts of the European Green Crab', presented at the American Agricultural Economics Association Annual Meeting, Portland, Oregan, United States.

Ludyanskiy, MLD, McDonald, D & MacNeill, D 1999, 'Impact of the zebra mussel, a bivalve invader', *Bioscience*, vol. 43, pp. 533–544.

Lutzen, J 1981, 'Observations on the rhizocephalan barnacle *Sylon hippolytes* M. sars parasitic on the prawn *Spirontocaris lilljeborgi* (Danielssen)', *Journal of Experimental Marine Biology and Ecology*, vol. 50, pp. 231–254.

——1999, '*Styela clava* Herdman (Urochordata, Ascidiacea) a successful immigrant to North West Europe: ecology, propagation and chronology of spread', *Helgoländer Meeresuntersuchungen*, vol. 52, pp. 383–391.

Mackie, JA, Darling, JA & Geller, JB 2012, 'Ecology of cryptic invasions: latitudinal segregation among *Watersipora* (Bryozoa) species', *Scientific Reports*, vol. 2, pp. 871–881.

Mackie, JA, Keough, MJ & Christidis, L 2006, 'Invasion patterns inferred from cytochrome oxidase I sequences in three Bryozoans, *Bugula neritina*, *Watersipora subtorquata*, and *Watersipora arcuata*', *Marine Biology*, vol. 149, pp. 285–295.

Maguire, GB & Nell, JA 2007, 'History, status and future of oyster culture in Australia', *Oyster Research Institute News*, vol. 19, pp 3–12.

Manchenko, GP & Radashevsky, VI 1998, 'Genetic evidence for two sibling species within Polydora cf. ciliate (Polychaeta: Spionidae) from the Sea of Japan', *Marine Biology*, vol. 131, pp. 489–495.

Mareike, H, Putri, ZN & Mark, L 2015, 'Does transport on ship hulls mitigate the risk of establishment in Asian green mussels *Perna viridis*?', abstract, 9th International Conference on Marine BioInvasions, Sydney, 19–21 January.

Markert, A, Raupach, MJ, Segelken-Voigt, A & Wehrmann, A 2014, 'Molecular identification and morphological characteristics of native and invasive Asian brush-clawed crabs (Crustacea: Brachyura) from Japanese and German coasts: *Hemigrapsus penicillatus* (De Haan, 1835) versus *Hemigrapsus takanoi* Asakura & Watanabe 2005', *Organisms Diversity and Evolution*, vol. 14, pp. 369–382.

Marks, LM, Reed, DC & Obaza, AK 2017, 'Assessment of control methods for the invasive seaweed *Sargassum horneri* in California, USA', *Management of Biological Invasions*, vol. 8, no. 2, pp. 205–213.

Marks, LM, Salinas-Ruiz, P, Reed, DC, Holbrook, SJ, Culver, CS, Engle, JM, Kushner, DJ, Caselle, JE, Frewald, J, Williams, JP, Smith, JR, Anguilar-Rosas, LE & Kaplanis, NJ 2015, 'Range expansion of a non-native, invasive macroalgae *Sargassum horneri* (Turner) C. Agardh, 1820 in the eastern Pacific', *Bioinvasion Records*, vol. 4, no. 4, pp. 243–248.

Markula, A & Csurhes, S 2009, *Pest animal risk assessment—New Zealand green-lipped mussel*, draft report to Biosecurity Queensland.

Masterton, J 2007, 'Styela plicata', Smithsonian Marine Station at Fort Pierce, accessed 20 April 2017.

Matheson, K, McKenzie, CH, Gregory, RS, Robichaud, DA, Bradbury, IR, Snelgrove, PVR & Rose, GA 2016, 'Linking eelgrass decline and impacts on associated fish communities to the European green crab *Carcinus maenas* invasion', *Marine Ecology Progress Series*, vol. 548, pp. 31–45.

Matsuoka, N & Hatanaka, T 1998, 'Genetic differentiation among local Japanese populations of the starfish *Asterias amurensis* inferred from allozyme variation', *Genes & Genetic Systems*, vol. 73, pp. 59–64.

Maximovich, NV & Guerassimova, AV 2003, 'Life history characteristics of the clam *Mya arenaria* in the White Sea', *Helgoland Marine Research*, vol. 57, pp. 91–99.

McDonald, J, Bridgwood, S & Hourston, M 2015, 'Likelihood of Marine Pest introduction to the Indian Ocean Territories', *Fisheries Research Report No. 264*, Department of Primary Industries and Regional Development, Western Australia.

McEnnulty, FR, Bax, NJ, Schaffelke, B & Campbell, ML 2001, *A review of rapid response options for the control of ABWMAC listed introduced marine pest species and related taxa in Australian waters*, Centre for Research on Introduced Marine Pests, CSIRO, Hobart.

McFarland, K, Donaghy, L & Volety, AK 2013, 'Effect of acute salinity changes on hemolymph osmolality and clearance rate of the non-native mussel, *Perna viridis*, and the native oyster, *Crassostrea virginica*, in Southwest Florida', *Aquatic Invasions*, vol. 8, pp. 299–310.

McKindsey, CW, Landry, T, O'Beirn, FX & Davies, IM 2007, 'Bivalve aquaculture and exotic species: a review of ecological considerations and management issues', *Journal of Shellfish Research*, vol. 26, pp. 281–294.

McLeod, IA, Parsons, DM, Morrison, MA, Le Port, A & Taylor, RB 2011, ‘Factors affecting the recovery of soft-sediment mussel reefs in the Firth of Thames, New Zealand’, *Marine and Freshwater Research*, vol. 63, pp. 78–83

Mead, A, Carlton, JT, Griffiths, CL & Rius, M 2011, ‘Introduced and cryptogenic marine and estuarine species of South Africa’, *Journal of Natural History*, vol. 45. pp. 2463–2524.

Mendez, MM, Schwindt, E & Bortolus, A 2013, ‘Patterns of substrata use by the invasive acorn barnacle *Balanus glandula* in Patagonian salt marshes’, *Hydrobiologia*, vol. 700, no. 1, pp. 99–107.

MESA n.d., Northern Pacific Seastar—’Asterias amurensis‘, Marine Education Society of Australasia, accessed 20 April 2017.

Micklem, JM, Griffiths, CL, Ntuli, N & Mwake, M 2016, ‘The invasive Asian green mussel *Perna viridis* in South Africa: all that is green is not viridis’, *African Journal of Marine Science*, vol. 38, no. 2, pp. 2017–215.

Millar AJK & Kraft GT 1994, ‘Catalogue of marine brown algae (Phaeophyta) of New South Wales, including Lord Howe Island, South-western Pacific’, *Australian Systematic Botany*, vol. 7, pp. 1–46.

Minchin, D 1999, ‘*Crepidula fornicata* (Linneaus, 1758), Calyptraeidae, Gastropoda’, in: *Exotics across the ocean. Case histories on introduced species: their general biology, distribution, range expansion and impact*, University of Kiel, Germany, Department of Fishery Biology, Institute for Marine Science, pp. 43–48.

——2008, ‘Crepidula fornicata’, Delivering Alien Invasive Species Inventories for Europe (DAISIE), accessed 27 October 2016.

Minchin, D, Davis, MH & Davis, ME 2006, ‘Spread of the Asian tunicate Styela clava Herdman, 1882 to the east and south-west coasts of Ireland’, *Aquatic Invasions*, vol. 1, pp. 91–96.

Minchin, D & Duggan, CB 1988, ‘The distribution of the exotic ascidian, *Styela clava* Herdman, in Cork Harbour’, *The Irish Naturalists’ Journal*, vol. 22, pp. 388–393.

Molnar, JL, Gamboa, RL, Revenga, C & Spalding, MD 2008, ‘Assessing the global threat of invasive species to marine biodiversity’, *Frontiers in Ecology and Environment*, vol. 6, pp. 485–492.

Montaudouin, X, Audemard, PJ & Labourg, C 1999, ‘Does the slipper limpet (*Crepidula fornicata*, L.) impair oyster growth and zoobenthos diversity? A revised hypothesis’, *Journal of Experimental Marine Biology and Ecology*, vol. 235, no. 1, pp. 105–124.

Montes, M, Rico, JM, Garcia-Vazquez, E & Borrell, YJ 2016, ‘Morphological and molecular methods reveal the Asian alga *Grateloupia imbricata* (Halymeniaceae) occurs on Cantabrian Sea shores (Bay of Biscay)’, *Phycologia*, vol. 55, no. 4, pp. 365–370.

Morris, RH, Abbott, DP & Haderlie, EC 1980, ‘*Balanus glandula’*, in *Intertidal Invertebrates of California*, Stanford University Press, California, United States.

Morton, B 1987, ‘Recent marine introductions into Hong Kong’, *Bulletin of Marine Science*, vol. 41, no. 2, pp. 503–513.

——1989, 'Life-history characteristics and sexual strategy of *Mytilopsis sallei* (Bivalvia: Dreissenidae) introduced into Hong Kong', *Journal of Zoology*, vol. 219, pp. 469–485.

——1996, 'The aquatic nuisance species problem: a global perspective and review', in *Zebra Mussels and Other Aquatic Nuisance Species*, Ann Arbor Press, Michigan.

Mulas, M & Bertocci, I 2016, 'Devil's tongue weed (*Grateloupia turuturu* Yamada) in northern Portugal: Passenger or driver of change in native biodiversity?', *Marine Environmental Research*, vol. 118, pp. 1–9.

Muñoz, J & McDonald, J 2014, 'Potential Eradication and Control Methods for the Management of the Ascidian Didemnum perlucidum in Western Australia', *Fisheries Research Report No. 252*, Department of Primary Industries and Regional Development, Western Australia.

Murphy, B & Paini, D 2010, *CCIMPE Review: Update 2007–2009*, unpublished CSIRO report for CCIMPE/NIMPIS, Australia.

Naser, MD, Page, TJ, Ng, NK, Apel, M, Yasser, AG, Bishop, JM, Ng, PKL & Clark, PF 2012, 'Invasive records of *Eriocheir hepuensis* Dai, 1991 (Crustacea: Brachyura: Grapsoidea: Varunidae): Implications and taxonomic considerations', *BioInvasions Records*, vol. 1, pp. 71–86.

Naser, MD, Rainbow, PS, Clark, PF, Yasser, AG & Jones, DS 2015, 'The barnacle *Amphibalanus improvisus* (Darwin, 1954), and the mitten crab *Eriocheir*: one invasive species getting off on another!', *BioInvasions Records*, vol. 4, no. 3, pp. 205–209.

National Biosecurity Committee 2016, *National framework for the management of established pests and diseases of national significance*, National Biosecurity Committee, Department of Agriculture and Water Resources, Canberra.

Neckles, HA 2015, 'Loss of eelgrass in Casco Bay, Maine, linked to green crab disturbance', *Northeastern Naturalist*, vol. 22, no. 3, pp. 478–500.

New Zealand MPI 2013, 'Styela clava' factsheet, Ministry of Primary Industries, Wellington.

Nichols, FH, Thompson, JK & Schemel, LE 1990, 'Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam *Potamocorbula amurensis*. II. Displacement of a former community', *Marine Ecology Progress Series*, vol. 66, no. 1–2, pp. 96–102.

Nicolini, MH & Penry, DL 2000, 'Spawning, fertilization, and larval development of *Potamocorbula amurensis* (Mollusca: Bivalvia) from San Francisco Bay, California', *Pacific Science*, vol. 54, no. 4, pp. 377–388.

NIMPIS 2009, NIMPIS database, National Introduced Marine Pest Information System, accessed 5 July 2017.

——2017a, 'Apollonia melanostomus' (Pallas 1814) (round goby) general information, National Introduced Marine Pest Information System, accessed April 2017.

——2017b, 'Callinectes sapidus' general information, National Introduced Marine Pest Information System, accessed 20 April 2017.

——2017c, 'Carcinus maenas' general information, National Introduced Marine Pest Information System, accessed 18 April 2017.

——2017d, 'Charybdis japonica' general information, National Introduced Marine Pest Information System, accessed 19 April 2017.

——2017e, 'Codium fragile' spp. fragile general information, National Introduced Marine Pest Information System, accessed 13 April 2017.

——2017f, 'Didemnum vexillum' Australian detections and potential range map, National Introduced Marine Pest Information System, accessed 26 April 2017.

——2017g, 'Eriocheir sinensis' general information, National Introduced Marine Pest Information System, accessed 19 May 2017.

——2017h, 'Hemigrapsus sanguineus' general information, National Introduced Marine Pest Information System, accessed 28 February 2017.

——2017i, 'Hemigrapsus takanoi' general information, National Introduced Marine Pest Information System, accessed 28 February 2017.

——2017j, 'Mya arenaria' general information, National Introduced Marine Pest Information System, accessed 5 April 2017.

——2017k, 'Mytilopsis sallei' reproduction and habitat, National Introduced Marine Pest Information System, accessed 13 April 2017.

——2017l, 'Perna viridis' general information, National Introduced Marine Pest Information System, accessed 10 April 2017.

——2017m, 'Pseudopolydora paucibranchiata' (Japanese polydorid) general information, National Introduced Marine Pest System, accessed April 2017.

——2017n, 'Pyromaia tuberculata' additional information, National Introduced Marine Pest Information System, accessed 27 April 2017.

——2017o, 'Rhithropanopeus harrisii' general information, National Introduced Marine Pest Information System, accessed 1 March 2017.

——2017p, 'Sabella spallanzanii' (European fan worm) general information, National Introduced Marine Pest Information System, accessed April 2017.

——2017q, 'Sargassum muticum' general information, National Introduced Marine Pest Information System, accessed 1 March 2017.

——2017r, 'Styela clava' general information, National Introduced Marine Pest Information System, accessed 20 April 2017.

——2017s, 'Styela plicata' general information, National Introduced Marine Pest Information System, accessed 20 April 2017.

——2017t, ‘Teredo navalis’ (naval shipworm) general information, National Introduced Marine Pest Information System, accessed April 2017.

——2017u, ‘Undaria pinnatifida’ general information, National Introduced Marine Pest Information System, accessed 4 April 2017.

NIWA n.d., The Invasive sea squirt (‘Styela clava’) fact sheet, National Institute of Water and Atmospheric Research, accessed 20 April 2017.

NOAA 2016, Blue crab, National Oceanic and Atmospheric Administration, Chesapeake Bay Office, Maryland, accessed April 2017.

NPS n.d., ‘*Mya arenaria’ Marine Invasive Factsheet*, National Park Service, US Department of the Interior, Washington, DC.

Nyberg CD, Thomsen MS & Wallentinus, I 2009, ‘Flora and fauna associated with the introduced red alga *Gracilaria vermiculophylla*’, *European Journal of Phycology*, vol. 44, no. 3, pp. 395–403.

Nyberg, CD & Wallentinus, I 2009, ‘Long-term survival of an introduced red alga in adverse conditions’, *Marine Biology Research*, vol. 5, no. 3, pp. 304–308.

Oliver, PG, Holmes, AM & Mettam, C 1998, ‘*Mytilopsis leucophaeata* (Conrad, 1831) [Bivalvia: Dreissenoidea]. A species new to the British fauna’, *Journal of Conchology*, vol. 36, pp. 13–18.

O’Loughlin, E, McCloud, C, Sierp, M & Westphalen G 2006, *Temperature and Salinity tolerances of priority marine pests*, report for PIRSA Biosecurity, South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

Pannell, A & Coutts, ADM 2007, *Treatment methods used to manage Didemnum vexillum in New Zealand*, Cawthron Institute for Biosecurity New Zealand, Nelson.

Parry, GD & Cohen, BF 2001a, *The distribution, abundance and population dynamics of the exotic seastar Asterias Amurensis during the first three years of its invasion of Port Phillip Bay, (incorporating a Report on the Bay Pest Day, 2 April 2000)*, Marine and Freshwater Resources Institute, Victoria.

——2001b, ‘Exotic species established in Western Port, including an assessment of the status of the exotic species *Corbula gibba, Alexandrium spp, Gymnodinium spp.* and *Undaria pinnatifida*’, *Marine and Freshwater Resources Institute Report No. 45*, Marine and Freshwater Resources Institute, Queenscliff.

Parry, GD, Werner, G & Heislers, S 2003, *Population dynamics of Asterias amurensis in Port Phillip Bay 1999–2003*, report to the Victorian Department of Sustainability and Environment by Victorian Primary Industries Research. Queenscliff, Victoria.

Pathy, DA & Mackie, GL 1993, ‘Comparative shell morphology of *Dreissena polymorpha*, *Mytilopsis leucophaeata*, and the "quagga" mussel (Bivalvia: Dreissenidae) in North America’, *Canadian Journal of Zoology*, vol. 71, no. 5, pp. 1012–1023.

Perdikaris, C, Konstantinidis, E, Gouva, E, Ergolavou, A, Klaoudatos, Nathanailides, C & Paschos, I 2016, ‘Occurrence of the invasive crab species *Callinectes sapidus* Rathbun, 1896, in NW Greece’, *Walailak Journal of Science and Technology*, vol. 13, no. 7, pp. 503–510.

Petersen, KS, Rasmussen, KL, Heinemeier, J & Rud, N 1992, ‘Clams before Columbus?’, *Nature*, vol. 359, pp. 679.

Peterson, C 2006, ‘Range expansion in the northeast Pacific by an estuary mud crab—a molecular study’, *Biological Invasions*, vol. 8, pp. 565–576.

Pierri, BS, Fossari, TD & Magalhaes, ARM 2016, ‘The brown mussel *Perna perna* in Brazil: native or exotic?’, *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, vol. 68, no. 2, pp. 404–414.

Pineda, MC, López-Legentil, S & Turon, X 2011, ‘The whereabouts of an ancient wanderer: global phylogeography of the solitary ascidian *Styela plicata*’, *PLoS ONE*, vol. 6, no. 9, pp. e25495.

Piola, RF, Dunmore, RA & Forrest, BM 2010, ‘Assessing the efficacy of spray delivered eco-friendly chemicals for the control and eradication of marine fouling pests’, *Biofouling*, vol. 26, no. 2, pp. 187–203.

Poore, GCB 2004, *Marine decapod crustacea of southern Australia: a guide to identification*, CSIRO Publishing, Collingwood.

Poore, GCB & Syme, A 2009, ‘Barnacles’, *A Museum Victoria Field Guide to Marine Life*, Museum Victoria, Melbourne.

Poupin, J, Davie, PJ & Cexus, J 2005, ‘A revision of the genus Pachygrapsus Randall, 1840 (Crustacea: Decapoda: Brachyura, Grapsidae), with special reference to the Southwest Pacific species’, *Zootaxa* 1015, Magnolia Press, Auckland, New Zealand, accessed April 2017.

Poupin, J & Juncker, M 2010, *A guide to the decapod crustaceans of the South Pacific*, Secretariat of the Pacific Community, Noumea, New Caledonia.

Poux, C, Gothland, M, Holl, AC, Spilmont, N, Arnaud, JF 2015, ‘Highly polymorphic microsatellite markers in two species, the invasive shore crabs *Hemigrapsus sanguineus* and *Hemigrapsus takanoi* (Decapoda, Varunidae)’, *Conservation Genetics Resources*, vol. 7, pp. 569–572.

Powell, AWB 1979, *New Zealand mollusca—marine, land and freshwater shells*, Collins, Auckland, New Zealand.

Projecto-Garcia, J, Cabral, H, & Schubart, CD 2010, ‘High regional differentiation in a North American crab species throughout its native range and invaded European waters: a phylogeographic analysis’, *Biological Invasions*, vol. 12, pp. 253–263.

Provan, J, Booth, D, Todd, NP, Beatty, GE & Maggs, CA 2007, ‘Tracking biological invasions in space and time: elucidating the invasive history of the green alga *Codium fragile* using old DNA’, *Diversity and Distributions*, vol. 14, no. 2, pp. 343–354.

Queiroga, H 1996, ‘Distribution of the crab *Carcinus maenas* (L.) (Decapoda, Portunidae) larvae over the continental shelf off northern Portugal in April 1991’, *Journal of Plankton Research*, vol. 18, pp. 1981–2000.

Rajagopal, S, Van der Gaag, M, Van der Velde, G & Jenner, HA 2005, ‘Upper temperature tolerances of exotic brackish water mussel, *Mytilopsis leucophaeta* (Conrad): an experimental study’, *Marine Environmental Research*, vol. 60, pp. 512–530.

Rajagopal, S, Van der Velde, G & Jenner, H 1997, ‘Shell valve movement response of dark false mussel, *Mytilopsis leucophaeta*, to chlorination’, *Water Research*, vol. 31, pp. 3187–3190.

Rajagopal, S, Venugoplalan, VP, van der Velde, G, & Jenner, HA 2006, ‘Greening of the coasts: a review of the *Perna viridis* success story’, *Aquatic Ecology*, vol. 40, pp. 273–297.

Ray, WJ & Corkum, LD 2001, ‘Habitat and site affinity of the round goby’, *Journal of Great Lakes Research*, vol. 27, pp. 329–334.

Razek, FAA, Ismaiel, M & Ameran, MAA 2016, ‘Occurrence of the blue crab *Callinectes sapidus*, Rathbun, 1896, and its fisheries biology in Barawil Lagoon, Sinai Peninsula, Egypt’, *The Egyptian Journal of Aquatic Research*, vol. 42, no. 2, pp. 223–229.

Read, G, ten Hove, H, Fiege, D, Bellan, G 2016, ‘Hydroides elegans’ (Haswell, 1883) [nomen protectum], in G Read & K Fauchald (eds), World Polychaeta Database, accessed through World Register of Marine Species 15 May 2017.

Reece, KS, Cordes JF, Stubbs, JB, Hudson, KL, & Francis, EA 2008, ‘Molecular phylogenies help resolve taxonomic confusion with Asian *Crassostrea* oyster species’, *Marine Biology*, vol. 153, pp. 709.

Reise, K, Gollasch, S & Wolff, WJ 1999, ‘Introduced marine species of the North Sea coasts’, *Helgolander Meeresunterers*, vol. 52, pp. 219–234.

Relini, G, Relini, M & Torchia, G 2000, ‘The role of fishing gear in the spreading of allochthonous species: the case of *Caulerpa taxifolia* in the Liguria Sea’, *ICES Journal of Marine Science*, vol. 57, pp. 1421–1427.

Richmond, L, Darbyshire, R, & Summerson, R 2010, *Determining the potential range of invasive marine pests for cost sharing*, ABARES, Canberra.

Rintelen, T & Van Damme, D 2011, ‘Dreissena bugensis’, The IUCN Red List of Threatened Species 2011, e.T188911A8661357, accessed 15 May 2017.

Roche, D 2008, ‘Discovery, distribution, and eradication potential of the introduced mud crab, *Rhithropanopeus harrisii*, in the Panama Canal’, thesis, McGill University, Montreal, Canada.

Roche, DG & Torchin, ME 2007, ‘Established population of the North American Harris mud crab, *Rhithropanopeus harrisii* (Gould, 1841) (Crustacea: Brachyura: Xanthidae) in the Panama Canal’, *Aquatic Invasions*, vol. 2, no. 3, pp. 155–161.

Rosenberg, G, & Gofas, S 2012, ‘Brachidontes pharaonis’ (P. Fischer, 1870), MolluscaBase (2017), accessed through World Register of Marine Species 15 May 2017.

Ross, DJ, Johnson, CR & Hewitt, CL 2002, 'Impact of introduced seastars *Asterias amurensis* on survivorship of juvenile commercial bivalves *Fulvia tenuicostata*', *Marine Ecology Progress Series*, vol. 241, pp. 99–112.

——2003a, 'Assessing the ecological impacts of an introduced seastar: the importance of multiple methods', *Biological Invasions*, vol. 5, pp. 3–21.

——2003b, 'Variability in the impact of an introduced predator (*Asterias amurensis*: Asteroidea) on soft-sediment assemblages', *Journal of Experimental Marine Biology and Ecology*, vol. 288, pp. 257–278.

——2006, 'Abundance of the introduced seastar, *Asterias amurensis*, and spatial variability in soft sediment assemblages in SE Tasmania: Clear correlations but complex interpretation', *Estuarine, Coastal and Shelf Science*, vol. 67, pp. 695–707.

Ross, DJ, Johnson, CR, Hewitt, CL & Ruiz, GM 2004, 'Interaction and impacts of two introduced species on a soft-sediment marine assemblage in SE Tasmania', *Marine Biology*, vol. 144, pp. 747–756.

Rudnick, D, Veldhuizen, T, Tullis, R, Culver, CS, Hieb, K & Tsukimura, B 2005, 'A life history model for the San Francisco Estuary population of the Chinese mitten crab, *Eriocheir sinensis* (Decapoda: Grapsoidea)', *Biological Invasions*, vol. 7, pp. 333–350.

Ruelas-Inzunza, JR & Paez-Osuna, F 2000, 'Comparative bioavailability of trace metals using three filter-feeding organisms in a subtropical coastal environment', *Environmental Pollution*, vol. 107, pp. 437–444.

Rueness, J 2005, 'Life history and molecular sequences of *Gracilaria vermiculophylla* (Gracilariales, Rhodophyta), a new introduction to European waters', *Phycologia*, vol. 44, no. 1, pp. 120–128.

Russ, GR 1977, *A comparison of the marine fouling occurring at the two principal Australian naval dockyards*, Department of Defence, Melbourne.

Rylander, K, Perez, J & Gomez, J 1996a, 'The distribution of the brown mussel, *Perna perna* and the green mussel, *Perna viridis* (Mollusca: Bivalvia: Mytilidae) in North-eastern Venezuela', *Caribbean Marine Studies*, vol. 5, pp. 86–87.

——1996b, 'Status of the green mussel, *Perna viridis* (Linnaeus, 1758) (Mollusca: Mytilidae), in north-eastern Venezuela', *Caribbean Marine Studies*, vol. 5, pp. 86–87.

Sá, FS de, Nalesso, RC & Paresque, K 2007, 'Fouling organisms on *Perna perna* mussels: is it worth removing them?', *Brazilian Journal of Oceanograpohy*, vol. 55, no. 2, pp. 155–161.

Sanamyan, K & Monniot, C 2007, Styela plicata (Lesueur, 1823), in N Shenkar, A Gittenberger, G Lambert, M Rius, R Moreira Da Rocha, BJ Swalla & X Turon (eds), *Ascidiacea World Database*, accessed through World Register of Marine Species 20 April 2017.

Saoud, IP, Kreydiyyeh, S, Chalfoun, A & Fakih, M 2007, 'Influence of salinity on survival, growth, plasma osmolality and gill Na+-K+ATPase activity in the rabbitfish, *Siganus rivulatus*', *Journal of Experimental Marine Biology and Ecology*, vol. 348, pp. 183–190.

Saoud, IP, Mohanna, C & Ghanawi, J 2008, 'Effects of temperature on survival and growth of juvenile spinefoot rabbitfish (*Siganus rivulatus*)', *Aquaculture Research*, vol. 39, pp. 491–497.

Saunders, GW 2009, 'Routine DNA barcoding of Canadian Gracilariales (Rhodophyta) reveals the invasive species *Gracilaria vermiculophylla* in British Columbia', *Molecular Ecology Resources*, vol. 9, pp. 140–150.

Saunders, GW, Birch, TC & Dixon, KR 2015, 'A DNA barcode survey of *Schizymenia* (Nemastomatales, Rhodophyta) in Australia and British Columbia reveals overlooked diversity including *S. tenuis* sp. nov. and *Predaea borealis* sp. nov.', *Botany*, vol. 93, pp. 859–871.

Saunders, GW & Withall, RD 2006, 'Collections of the invasive species *Grateloupia turuturu* (Halymeniales, Rhodophyta) from Tasmania, Australia', *Phycologia*, vol. 45, no. 6, pp. 711–714.

Savoya, V & Schwindt, E 2010, 'Effect of the substratum in the recruitment and survival of the introduced barnacle *Balanus glandula* (Darwin 1854) in Patagonia, Argentina', *Journal of Experimental Marine Biology and Ecology*, vol. 382, pp. 125–130.

Schaffelke, B & Deane, D 2005, 'Dessication tolerance of the introduced marine green alga *Codium fragile* ssp. *tomentosoides*—clues for likely transport vectors?', *Biological Invasions*, vol. 7, pp. 557–565.

Schultz, MP, Bendick, JA, Holm ER & Hertel, WM 2011, 'Economic impact of biofouling on a naval surface ship', *Biofouling: The Journal of Bioadhesion and Biofilm Research*, vol. 27, pp. 87–89.

Schwindt, A 2007, 'The invasion of the acorn barnacle *Balanus glandula* in the south-western Atlantic 40 years later', *Journal of the Marine Biological Association of the United Kingdom*, vol. 87, no. 5, pp. 1219–1225.

Segnini, M, Chung, KS, & Pérez, JE 1998, 'Salinity and temperature tolerances of the green and brown mussels, *Perna viridis* and *Perna perna* (Bivalvia: Mytilidae)', *Revista de Biologia Tropical*, supplement 46, pp. 121–126.

Shanks, AL, Grantham, BA & Carr, MH 2003, 'Propagule dispersal distance and the size and spacing of marine reserves', *Ecological Applications*, vol. 13, pp. S159–S169.

Shields, JD & Behringer Jr, DC 2004, 'A new pathogenic virus in the Caribbean spiny lobster *Panulirus argus* from the Florida Keys', *Diseases of Aquatic Organisms*, vol. 59, pp. 109–118.

Shinji, J, Strussmann, CA, Wilder, MN & Watanabe, S 2009, 'Short-term responses of the adults of the common Japanese intertidal crab, *Hemigrapsus takanoi* (Decapoda: Brachyura: Grapsoidea) at different salinities: osmoregulation, oxygen consumption, and ammonia excretion', *Journal of Crustacean Biology*, vol. 29, no. 2, pp. 269–272.

Shipman, CM 2015, *Chesapeake Bay Blue Crabs and consumption related illness*, thesis, James Madison University, Virginia.

Siddall, SE 1980, 'A clarification of the genus *Perna* (Mytilidae)', *Bulletin of Marine Science*, vol. 30, pp. 858–870.

Simon-Blecher, N, Granevitze, Z & Achituv, Y 2008, '*Balanus glandula*: from North-West America to the west coast of South Africa', *African Journal of Marine Science*, vol. 30, pp. 85–92.

Simpfendorfer, RW, Oelckers, KB & Lopez, DA 2006, 'Phosphofructokinase from muscle of the marine giant barnacle *Austromegabalanus psittacus*: Kinetic characterisation and effect of in vitro phosphorylation', *Comparative Biochemistry and Physiology Part C: Toxicology and Pharmacology*, vol. 142, pp. 382–389.

Simpson, TJS, Dias, PJ, Snow, M, Muñoz, J & Berry, T 2016, 'Real-time PCR detection of *Didemnum perlucidum* (Monniot, 1983) and *Didemnum vexillum* (Kott, 2002) in an applied routine marine biosecurity context', *Molecular Ecology Resources*, vol. 17, no. 3, pp. 443–453.

Sinner, J, Forrest, BM, & Taylor, M 2000, 'A strategy for managing the Asian kelp Undaria, Final report', *Cawthron Report No. 578*, Cawthron Institute, Nelson, New Zealand.

Smale, DA & Childs, S 2012, 'The occurrence of a widespread marine invader, *Didemnum perlucidum* (Tunicata, Ascidiacea) in Western Australia', *Biological Invasions*, vol. 14, pp. 1325–1330.

Smith, PJ, Webber, WR, McVeagh, SM, Inglis, GJ & Gust, N 2003, 'DNA and morphological identification of an invasive swimming crab, *Charybdis japonica*, in New Zealand waters', *New Zealand Journal of Marine and Freshwater Research*, vol. 37, pp. 753–762.

Soot-Ryen, T 1955, 'A report on the Mytilidae', *Allan Hancock Pacific Expedition*, vol. 20, pp. 1–154.

South, PM & Thomsen, MS 2016, 'The ecological role of invading *Undaria pinnatifida*: an experimental test of the driver-passenger models', *Marine Biology*, vol. 163, pp. 175.

Southward, A 2013, 'Solidobalanus fallax' (Broch, 1927), World Register of Marine Species, accessed 27 October 2016.

Southward, AJ, Hiscock, K, Kerckhof, F, Moyse, J & Elfimov, AS 2004, 'Habitat and distribution of the warm-water barnacle *Solidobalanus fallax* (Crustacea: Cirripedia)', *Journal of the Marine Biological Association of the United Kingdom*, vol. 84, pp. 1169–1177.

Souza, JRB de, Rocha, CMC, da & Lima, M dos PR de 2005, 'Occurrence of exotic bivalve *Mytilopsis leucophaeta* (Conrad) (Mollusca, Bivalvia), in Brazil', *Revista Brasileirade Zoologia*, vol. 22, no. 4, pp. 1204–1206.

Spencer, HG, Willan, RC, Marshall, BA & Murray, T 2016, Checklist of the living mollusca recorded from the New Zealand Exclusive Economic Zone, accessed 27 October 2016.

Spinuzzi, S, Schneider, K, Walters, L, Yuan, W & Hoffman, EA 2013, 'Tracking the distribution of non-native marine invertebrates (*Mytella charruana*, *Perna viridis* and *Megabalanus coccopoma*) in the south-eastern USA', *Marine Biodiversity Records*, vol. 6, pp. 55–67.

Stafford, H, Willan, RC & Neil, KM 2007, 'The invasive Asian green mussel, *Perna viridis* (Linnaeus, 1758) (Mollusca: Mytilidae), breeds in Trinity Inlet, tropical northern Australia', *Molluscan Research*, vol. 27, no. 2, pp. 105–109.

Stasolla, G & Innocenti, G 2014, 'New records of the invasive crabs *Callinectes sapidus* Rathbun, 1896 and *Percnon gibbesi* (H. Milne Edwards, 1853) along the Italian coasts', *BioInvasions Records*, vol. 3, pp. 39–43.

Stearns, REC 1881, '*Mya arenaria* in San Francisco Bay', *American Naturalist*, vol. 15, pp. 142–146.

Stefaniak, L, Zhang, H, Gittenberger, A, Smith, K, Holsinger, K, Lin S & Whitlatch, RB 2012, 'Determining the native region of the putatively invasive ascidian *Didemnum vexillum* Kott, 2002', *Journal of Experimental Marine Biology and Ecology*, vol. 422–423, pp. 64–71.

Strasser, M 1999, '*Mya arenaria—*an ancient invader of the North Sea coast', *Helgolander Meeresuntersuchungen*, vol. 52, pp. 320–324.

Strayer, DL 2009, 'Twenty years of zebra mussels: lessons from the mollusk that made headlines', *Frontiers in Ecology and Environment*, vol. 7, pp. 135–141.

Subba Rao, DV 2005, 'Comprehensive review of the records of the biota of the Indian Seas and introduction of non-indigenous species', *Aquatic Conservation, Marine and Freshwater Ecosystems*, vol. 15, pp. 117–146.

Summerson, R, Skirton, M, Mazur, K, Arthur, T, Curtotti, R & Smart, R 2013, *Economic evaluation of the costs of biosecurity response options to address an incursion of 'Mytilopsis sallei' (black-striped mussel) into Australia*, ABARES report for Plant Health Australia, Canberra.

Switzer, SE, Therriault, TW, Dunham, A & Pearce, CM 2011, 'Assessing potential control options for the invasive tunicate *Didemnum vexillum* in shellfish aquaculture', *Aquaculture*, vol. 318, pp. 145–153.

Tan, EBP & Beal, BF 2015, 'Interactions between the invasive European green crab, *Carcinus maenas* (L.), and juveniles of the soft-shell clam, *Mya arenaria* L., in eastern Maine, USA', *Journal of Experimental Marine Biology and Ecology*, vol. 462, pp. 62–73.

Tan, KS & Morton, B 2006, 'The invasive Caribbean bivalve *Mytilopsis sallei* (Dreisenidae) introduced into Singapore and Johor Bahru, Malaysia', *Raffles Bulletin of Zoology*, vol. 54, pp. 429–434.

Tan, SKT & Woo, HPM 2010, *A Preliminary Checklist of the Molluscs of Singapore*, National Museum of Singapore, Singapore.

Tanacredi, JT, Botton, ML & Smith, DR 2009, *Biology and conservation of horseshoe crabs*, Springer, New York.

Tanu, MB, & Noguci, T 1999, 'Tetrodotoxin as a toxic principle in the horseshoe crab *Carcinoscorpius rotundicauda* collected from Bangladesh', *Food Hygiene and Safety Science (Shokuhin Eiseigaku Zasshi)*, vol. 40, pp. 426–430.

Tasmanian Planning Commission 2009, 'Indicators: Estuarine and Marine Pests and Diseases', *State of the Environment Tasmania Report 2009,* Tasmanian Planning Commission, Tasmania, accessed 20 April 2017.

Therriault, TW, Docker, MF, Orlova, MI, Heath, DD & MacIsaac, HJ 2003, 'Molecular resolution of the family Dreissenidae (Mollusca: Bivalvia) with emphasis on Ponto-Caspian species, including first report of *Mytilopsis leucophaeata* in the Black Sea basin', *Molecular Phylogenetics and Evolution*, vol. 30, pp. 479–489.

Therriault, TW, Weise, AM, Higgins, SN, Guo, Y & Duhaine, J 2012, Risk Assessment for Three Dreissenid Mussels ('Dreissena polymorpha', 'D. rostriformis bugensis' and 'Mytilopsis leucophaeata') in Canadian Freshwater Ecosystems, Canadian Science Advisory Secretariat, document 2012/174.

Thiyagarajan, V & Qian, PY 2003, 'Effect of temperature, salinity and delayed attachment on development of the solitary ascidian *Styela plicata* (Lesueur)', *Journal of Experimental Marine Biology and Ecology*, vol. 290, pp. 133–146.

Thompson, JK & Parchaso, F 2012, Conceptual Model for 'Potamocorbula amurensis', DRERIP Conceptual Model, Sacramento (CA), Ecosystem Restoration Program, accessed 27 October 2016.

Thomsen, MS, Frederico, C, Gurgel, D, Fredericq, S, & McGlathery, KI 2006, '*Gracilaria vermiculophylla* (Rhodophyta, Gracilariales) in Hog Island Bay, Virginia: A cryptic alien and invasive macroalga and taxonomic correction', *Journal of Phycology*, vol. 42, pp. 139–141.

Thomsen, MS & McGlathery, KJ 2007, 'Stress tolerance of the invasive macroalgae *Codium Fragile* and *Gracilaria vermiculophylla* in a soft-bottom turbid lagoon', *Biological Invasions*, vol. 9, pp. 499–513.

Thomsen, MS, McGlathery, KJ & Tyler, AC 2006, 'Macroalgal distribution patterns in a shallow, soft-bottom lagoon, with emphasis on the nonnative *Gracilaria vermiculophylla* and *Codium fragile*', *Estuaries & Coasts*, vol. 29, pp. 465–473.

Thomsen, MS, Wernberg, T, Olden, JD, Byers, JE, Bruno, JF, Silliman, BR, Schiel, DR 2014, 'Forty years of experiments on aquatic invasive species: are study biases limiting our understanding of impacts?', *NeoBiota*, vol. 22, pp. 1–22.

Thorson, G 1950, 'Reproductive and larval ecology of marine bottom invertebrates', *Biological Reviews*, vol. 25, pp. 1–45.

Thresher, R, Proctor, C, Ruiz, G, Gurney, R, MacKinnon, W, Walton, L, Rodriguez, L & Bax, N 2003, 'Invasion dynamics of the European shore crab, *Carcinus maenas*, in Australia', *Marine Biology*, vol. 142, pp. 867–876.

Tomalin, BJ & Kyle, R 2015, 'Subsistence and recreational mussel (*Perna perna*) collecting in KwaZulu-Natal, South Africa: fishing mortality and precautionary management', *South African Journal of Zoology*, vol. 33, no. 1, pp.12–22.

Torchin, ME, Hechinger, RF, Huspeni, TC, Whitney, K & Lafferty, KD 2005, 'The introduced ribbed mussel (*Geukensia demissa*) in Estero de Punta Banda, Mexico: interactions with the native cord grass, *Spartina foliosa*', *Biological Invasions*, vol. 7, pp. 607–614.

Trowbridge, C 1999, *An Assessment of the Potential Spread and Options for Control of the Introduced Green Macroalga 'Codium fragile ssp. Tomentosoides' on Australian Shores*, CRIMP Consultancy Report, CSIRO, Tasmania.

A story of an invasive alien species, 'Rapana venosa', in the Black Sea 2014, YouTube video, Turkish Marine Research Foundation 2014, Instanbul.

van Beek, GCW 2006, 'The round goby *Neogobius melanostomus* first recorded in the Netherlands', *Aquatic Invasions*, vol. 1, pp. 42–43.

Van Damme, D 2014, 'Dreissena polymorpha', The IUCN Red List of Threatened Species 2014, e.T155495A42428801, accessed 15 May 2017.

van Soest, R 2008, 'Cliona thoosina' Topsent, 1888, World Porifera database, accessed through the World Register of Marine Species 8 May 2017.

Verween, A, Vincx, M & Degraer, S 2006, 'Growth patterns of *Mytilopsis leucophaeata*, an invasive biofouling bivalve in Europe', *Biofouling*, vol. 22, pp. 221–231.

Walton, WC, MacKinnon, C, Rodriguez, LF, Proctor, C & Ruiz, GM 2002, 'Effect of an invasive crab upon a marine fishery: green crab, *Carcinus maenas*, predation upon a venerid clam, *Katelysia scalarina*, in Tasmania (Australia)', *Journal of Experimental Marine Biology and Ecology*, vol. 272, pp. 171–189.

Wasson, K, Zabin, CJ, Bedinger, L, Diaz, MC & Pearse, JS 2001, 'Biological invasions of estuaries without international shipping: the importance of intraregional transport', *Biological Conservation*, vol. 102, pp. 143–153.

Watanabe, S, Metaxas, A & Scheibling, RE 2009, 'Dispersal potential of the invasive green alga *Codium fragile* ssp. *fragile*', *Journal of Experimental Marine Biology and Ecology*, vol. 381, no. 2, pp. 114–125.

Webb, S 2007, *Pathogens and parasites of the mussels 'Mytilus galloprovincialis' and 'Perna canaliculus': assessment of the threats faced by New Zealand aquaculture*, Cawthron Report 1334: 1–36, Nelson.

Webb, S 2008, 'Health status of green shell mussels', *New Zealand Aquaculture*, vol. 11, no. 22, Nelson.

Wells, FE, McDonald, JI & Huisman, JM 2008, *Introduced Marine Species in Western Australia*, Department of Primary Industries and Rural Development, Western Australia.

Western Australian Department of Fisheries 2016, Western Australian Prevention List for Introduced Marine Pests, Department of Primary Industries and Rural Development, Western Australia, accessed November 2016.

Wilkens, S & Allen, S 2015, 'Notes on the bivalve *Perna canaliculus* (Gmelin, 1791), recently detected on the Australian fishing vessel "Saxon Onward" in New Zealand', *New Zealand Ministry for Primary Industries Technical Paper 2015/MESN93*, New Zealand, pp. 1–6.

Willan, RC 1985, ‘Successful establishment of the Asian mussel *Musculista senhousia* (Benson in Cantor, 1842) in New Zealand’, *Records of Auckland Institute and Museum*, vol. 22, pp. 85–96.

——1987, ‘The mussel *Musculista senhousia* in Australasia: another aggressive alien highlights the need for quarantine at ports’, *Bulletin of Marine Science*, vol. 41, pp. 475–489.

Willan, RC, Russell, BC, Murfet, NB, Moore, KL, McEnnulty, FR, Horner, SK, Hewitt, CL, Dally, GM, Campbell, MI & Bourke, ST 2000, ‘Outbreak of *Mytilopsis sallei* in Australia’, *Molluscan Research*, vol. 20, pp. 25–30.

Womersley HBS 1967, *The Marine Benthic Flora of Southern Australia. Part II*, South Australian Government Printing Division, Adelaide.

Womersley, HBS 1984, ‘The Marine Benthic Flora of Southern Australia Part I’, in [‘Ulva australis’ Areschoug 1854: 370](), *Electronic Flora of South Australia*, Department for Environment and Water, South Australia, accessed 8 May 2017.

Womersley, HBS & Lewis, JA 1994, ‘Family Halymeniaceae Bory 1828: 158’, in, HBS Womersley, ‘The Marine Benthic Flora of Southern Australia: Part IIIA’, *Flora of Australia Supplementary Series No. 1*, Australian Biological Resources Study, Canberra, pp. 167–216,

‘’Wong, NA, Tooman, LK, Sewell, MA & Lavery, SD 2016, ‘The population genetics and origin of invasion of the invasive Asian paddle crab, *Charybdis japonica* (A Milne-Edwards, 1861) (Brachyura: Portunidae) in north-eastern New Zealand’, *Marine Biology*, vol. 163, pp. 133.

Wong, YT, Meier, R & Tan, KS 2011, ‘High haplotype variability in established Asian populations of the invasive Caribbean bivalve *Mytilopsis sallei* (Dreissenidae)’, *Biological Invasions*, vol. 13, pp. 341–348.

Wonham, MJ, Carlton, JT, Ruiz, GM, & Smith, LD 2000, ‘Fish and ships: relating dispersal frequency to success in biological invasions’, *Marine Biology*, vol. 136, pp. 1111–1121.

Wood, AR, Apte, S, MacAvoy, ES & Gardner, JPA 2007, ‘A molecular phylogeny of the marine mussel genus *Perna* (Bivalvia: Mytilidae) based on nuclear (ITS1&2) and mitochondrial (COI) DNA sequences’, *Molecular Phylogenetics and Evolution*, vol. 44, pp. 685–698.

Wrange AL, Charrier G, Thonig A, Rosenblad MA, Blomberg A, Havenhand JN, Johnsson, PR & Andre, C 2016, ‘The Story of a Hitchhiker: Population Genetic Patterns in the Invasive Barnacle *Balanus* (*Amphibalanus*) *improvisus* Darwin 1854’, *PLoS ONE*, vol. 11, no. 1, e0147082.

Yoshida, G, Yoshikawa, K & Terawaki, T 2001, ‘Growth and maturation of two populations of *Sargassum horneri* (Fucales, Phaeophyta) in Hiroshima Bay, the Seto Inland Sea’, *Fisheries Science*, vol. 67, pp. 1023–1029.

Yuan, W, Walters, LJ, Schneider, KR & Hoffman, EA 2010, ‘Exploring the survival threshold: a study of salinity tolerance of the nonnative mussel *Mytella charruana*’, *Journal of Shellfish Research*, vol. 29, no. 2, pp. 415–422.

Zaiko, O 2005, ‘*Crepidula fornicata*’, in S Olenin, E Leppakoski & D Daunys (eds), Baltic Sea Alien Species Database, accessed 27 October 2016.

Zeidler, W 1978, 'Note on the occurrence of the European shore crab *Carcinus maenas* (Linn, 1958) in Australia', *South Australian Naturalist*, vol. 53, pp. 11–12.

Zhan, A, Briski, E, Bock, DG, Ghabooli, S, MacIsaac, HJ 2015, 'Ascidians as models for studying invasion success', *Marine Biology*, vol. 162, pp. 2449–2470.