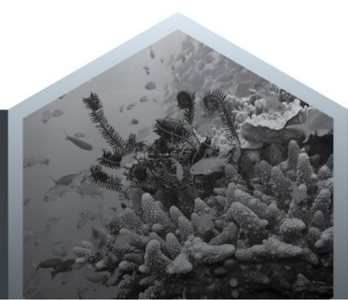
Australian Government

MARINE PESTS

# Rapid response manual for *Asterias amurensis*

Version 2.0, January 2020

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: Marine Pest Sectoral Committee 2020, *Rapid response manual for 'Asterias amurensis',* Department of Agriculture, Canberra. CC BY 4.0. Document modified in 2018 to meet accessibility requirements.

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

Marine Pest Sectoral Committee Secretariat
Department of Agriculture
GPO 858 Canberra ACT 2601
Email mpsc@agriculture.gov.au
Web marinepests.gov.au



**Note**

Rapid response manuals are a key element of the Australian Emergency Marine Pest Plan. They provide detailed information and guidance for emergency response to a marine pest incident. The guidance is based on sound analysis and links policy, strategies, implementation, coordination and emergency management plans.

# Preface

The Australian Government Department of Agriculture maintains a series of emergency response[1] documents to ensure national coordination of emergency responses to incursions by exotic pests and diseases or significant range expansions of established pests and endemic diseases. The Emergency Marine Pest Plan (EMPPlan) Rapid Response Manuals for marine pests provide detailed information and guidance for emergency response to key marine pest species or groups of pest species of national significance.

The EMPPlan is adapted from the Australian emergency plans for terrestrial and aquatic animal diseases—the Australian Veterinary Emergency Plan (AUSVETPLAN) and the Australian Aquatic Veterinary Emergency Plan (AQUAVETPLAN). The format and content have been kept as similar as possible to those documents to enable emergency response personnel trained in their use to work efficiently with these manuals in the event of a marine pest emergency.

This manual describes the principles for an emergency response to an incident caused by the suspicion or confirmation of incursion by the northern Pacific seastar, Asterias amurensis, a known invasive marine pest species. It is established in Australia, but not considered widespread. The species is listed on the Australian Priority Marine Pest List (https://www.marinepests.gov.au/what-we-do/apmpl). Dr Graeme Inglis and Ms Kimberley Seaward from the National Institute of Water and Atmospheric Sciences, New Zealand, and Ms Amy Lewis from the Department of Agriculture prepared the first edition of this Rapid Response Manual. The manual was revised as part of activity 3.5 of MarinePestPlan 2018-2023 (plan and implement procedures to develop and update the EMPPlan rapid response manuals and related guidance materials). The Marine Pest Sectoral Committee endorsed the second edition of this manual. The manual will be reviewed at least every five years to incorporate new information and experience gained with incursion management of these or similar marine pests. Amended versions will be published on the marine pest website.

[1] Note that the term 'emergency response' as used in this document does not refer to a 'biosecurity emergency' as that term is used under the *Biosecurity Act 2015*, nor do any activities described by this document undertaken during an 'emergency response' intended to be an exercise of powers provided by Chapter 8 (Biosecurity Emergencies and Human Biosecurity Emergencies) of that Act.

# Recommendations for amendments

Marine Pest Sectoral Committee Secretariat
Department of Agriculture
GPO 858 Canberra City ACT 2601
Email mpsc@agriculture.gov.au

# Contents

# Tables



# Figures



# Photographs



# Maps

# Introduction

Emergency response operations are most efficient if they are based on detailed knowledge of the life history, biology, ecology and susceptibility of the pest species to eradication and control measures. Species-specific rapid response manuals have been prepared for several marine pests that the Marine Pest Sectoral Committee (MPSC) has identified as being of national concern.

During an emergency response, detailed technical information must be collected in the investigation phase of the response. At a minimum, information will be needed on:

- the nature of the pest, including its:
  - taxonomy
  - known distribution (global/Australian, native/non-native)
  - life history and ecology
  - environmental tolerances
  - impact potential
- pathways and vectors by which the species may be spread
- methods to prevent spread of the organism
- methods for undertaking surveys to
  - delimit established populations
  - trace an incursion
  - monitor the effectiveness of management measures
- methods to control or eradicate pest populations in different marine environments
- federal, state and territory legislation and policy relevant to emergency responses.

This information must be assembled rapidly from reliable sources. Preference should be given to using primary sources of information, such as advice from scientists, engineers or other professionals with recognised expertise on the species or likely emergency operations, and from published, peer-reviewed literature. Reputable secondary sources of information, such as internet databases and 'grey' literature may be used to supplement this advice or to prepare summary information and plans for expert review.

This document provides guidance on:

- types of information needed to determine an appropriate response to the suspicion or confirmation of incursion by *Asterias amurensis*
- types of expert advice that may need to be sought
- potential sources of information for preparing a response plan
- appropriate methods for containment, control and/or eradication of established populations.

# 1 Nature of the pest

Understanding the life history, ecology and biology of a marine pest is fundamental to an effective emergency response. Detailed knowledge of a species allows better evaluation of the threat it is likely to pose, the feasibility of response options and the design of efficient methods for surveillance, containment, eradication and control.

## 1.1 *Asterias amurensis*

The northern Pacific seastar, *Asterias amurensis*, is highly invasive and capable of reaching high densities in invaded habitats (Lütken 1871). It is a highly fecund subtidal species that can undergo massive population growth under optimal environmental conditions. *A. amurensis* is an opportunistic predator that consumes a large variety of prey. In high densities, it can have severe effects on wild and cultured shellfish populations, and on native biodiversity in benthic habitats (NIMPIS 2002). It can have serious economic consequences for the aquaculture and fishing industries.

### 1.1.1 Taxonomy

**Table 1 Taxonomy of *Asterias amurensis***

| Classification | *Asterias amurensis* |
|---|---|
| Phylum | Echinodermata |
| Class | Asteroidea |
| Subclass | Asterozoa |
| Order | Forcipulata |
| Family | Asteriidae |
| Genus | *Asterias* |

Similar species present in Australian waters include *Uniophora granifera* and *U. dyscrita*. Related species overseas are *A. forbesi* (Gulf of Maine to Texas, United States), *A. rubens* (British and Irish coasts) and *A. vulgaris* (Atlantic coast, United States).

### 1.1.2 Diagnostic features for identification

*Asterias amurensis* can be identified in the field and in the laboratory.

#### 1.1.2.1 Field identification

*Asterias amurensis* typically has five arms that taper at the end to pointed tips that are generally turned upwards. A range of colour morphs are possible. The colour on the top and sides of the arms ranges from a uniform pale yellow with purple arm tips to mottled yellow-purple. The underside of the arms and central disc are a uniform yellow (Photo 1).

*A. amurensis* is a comparatively large seastar. Adults can reach diameters of up to 50 cm tip to tip. The body has numerous jagged spines arranged irregularly on the upper surface down the arms. A large central disc is present where the arms meet. A single line of spines runs down each arm on the underside along the groove containing the tube feet (NIMPIS 2002) (Figure 1).

The native seastar which most closely resembles *A. amurensis* is *U. granifera*. It can be distinguished from *A. amurensis* by the lack of pointed, upward-turned tips on its arms. *U. granifera* has rounded, blunter spines on its upper surface that are often arranged in a zigzag-like pattern (Photo 2).

## Photo 1 Adult *Asterias amurensis*

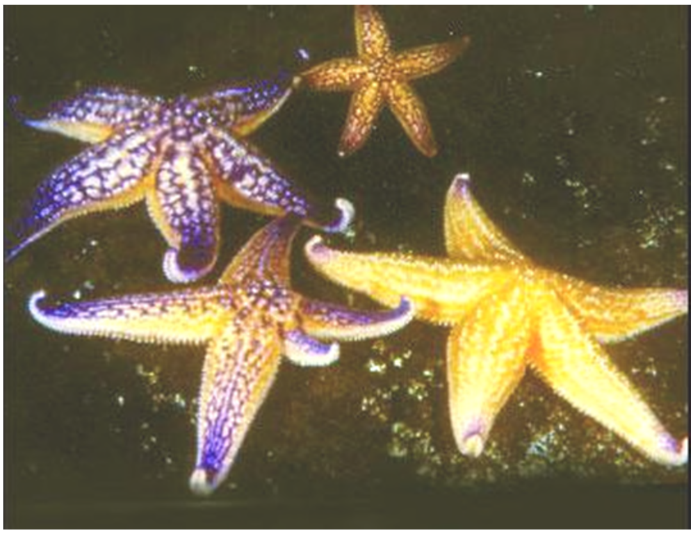


Image: Andrew Cohen, San Francisco Estuary Institute

## Figure 1 Diagnostic features of *Asterias amurensis*

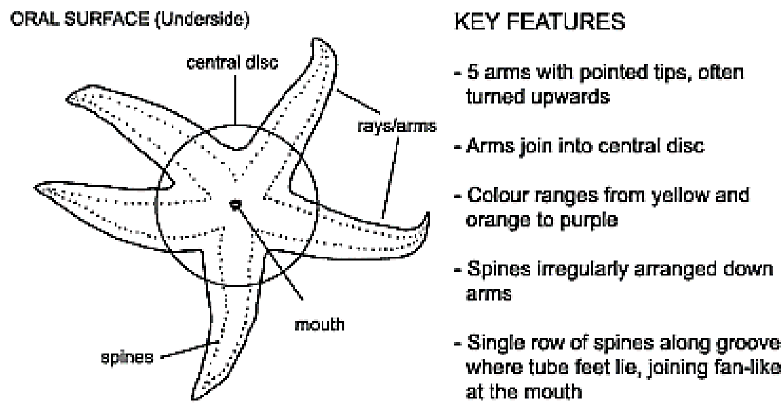



Image: CSIRO Marine Research

## Photo 2 Native seastar, *Uniophora granifera*

Image: Graham Edgar, University of Tasmania

#### 1.1.2.2 Laboratory identification

Specific identification of *Asterias amurensis* is possible using genetic methods. Polymerase chain reaction (PCR) amplification of mitochondrial DNA allows positive identification of both larval and adult seastars of the *Asterias* genus. This method is sufficiently sensitive to detect larvae at a density greater than three larvae per $m^3$ (Deagle et al. 2003). It allows detection of low densities of *Asterias* sp. even when mixed with larvae of other species (Bax et al. 2006; Deagle et al. 2003). A quantitative, real-time PCR test using a TaqMan probe that is specific for *A. amurensis* has also been developed (Bax et al. 2006).

Given that all species of the genus *Asterias* are considered marine pests in Australian waters, detection of any species in this genus would be of significance.

### 1.1.3 Life history and ecology

Understanding the ecology of *Asterias amurensis* involves examination of its reproduction, growth and life habit (Table 2).

**Table 2 *Asterias amurensis* life history summary**

| Feature | Measure |
|---|---|
| Maximum size (length) | 50 cm |
| Maximum age | 5 years |
| Mating strategy | Separate sexes (asexual reproduction is possible) |
| Type of mating | Broadcast spawner |
| Dispersal stage | Planktonic larva |
| Larval duration | 2–4 months |
| Time to sexual maturity | 1 year |
| Size at sexual maturity | Ray length 55 mm |
| Feeding mode | Generalist predator |
| Depth range | 1–200 m |
| Preferred habitat | Soft sediment |
| Distribution | Gregarious settlement |
| Salinity tolerance | 12–36 ppt |
| Temperature tolerance | 10–35 °C |

#### 1.1.3.1 Reproduction and growth

*Asterias amurensis* is a dioecious (separate male and female sexes) broadcast spawner (sheds viable eggs and sperm into the water column where fertilisation takes place) that becomes sexually mature after approximately one year, when its arm length is about 55 mm (based on monitoring of *A. amurensis* populations in Tasmania). Ripe females contain large ovaries with microscopic eggs. A single female can release up to 19 million eggs per year (Buttermore, Turner & Morrice 1994) which, after fertilisation, form long-lived planktotrophic bipinnaria and brachiolaria larvae that can remain in the water column for between six and 16 weeks (under laboratory conditions at 12 °C, larvae can take between 90 and 150 days to develop). This may result in larvae being transported substantial distances before reaching a suitable settlement location (Goggin 1998).

Settlement conditions have been suggested as important factors in the larval duration of this species. If conditions are not suitable, the larval life can be extended, leading to an overlap of larval generations (Byrne, Morrice & Wolf 1997). Delayed settlement could be a significant characteristic that increases the survival of *A. amurensis* in ballast water tanks and in successful invasion of new locations. Settlement of competent brachiolaria is most likely to occur on non-geniculate coralline algae rather than on mud, sand or mussel shells (Goggin 1998).

The timing of gamete development in *A. amurensis* (gametogenesis) is determined by a complex interaction between temperature and photoperiod. In Tasmania, an increased rate of gametogenesis in April coincided with the warmest sea temperatures recorded during the study period, while the commencement of spawning in July coincided with the coldest temperatures recorded during the study period (10–12 °C) (Byrne, Morrice & Wolf 1997). In Australia, there is also evidence of an extended period of spawning, as well as multiple spawning events. In Port Phillip Bay, larvae are present in the water between May and early November, with spawning occurring as early as April and peaking in August (Dommisse & Hough 2004). In the Derwent River estuary, the spawning period appears to be more protracted; larvae are present in the water between May and December and possibly persist into January (Dommisse & Hough 2004).

As a broadcast spawner, reproductive success in *A. amurensis* can be a function of the density and degree of aggregation of mature adults. Fertilisation success is likely to be greater when male and female *A. amurensis* spawn in close proximity.

Larvae of this species are difficult to identify morphologically because of their similarity to other Asteroid species present in Australia (such as *Coscinasterias muricata* and *Patiriella regularis*) and because of plasticity in the morphology of the larva. Larvae of the most closely related native Australian species, *U. granifera*, are more easily distinguished from those of *A. amurensis* because *U. granifera* has large lecithotrophic larvae. Larval identification should be confirmed using molecular methods (Sutton & Green 1999).

*A. amurensis* is also capable of reproducing asexually, by regenerating from the central disc. Damaged individuals can regenerate if at least one arm and part of the central disc remain. Large individuals (greater than 40 cm in diameter) are also capable of detaching limbs as a defensive mechanism (autotomy) when subject to attack or stress. Provided that a section of the central disc is present, regeneration may occur from both the detached limb and the remaining individual. The arm growth rate of *A. amurensis* is about 6 mm/month in the first year, after which growth slows to about 1–2 mm/month (NIMPIS 2002). Fully grown individuals can reach 40–50 cm in diameter, and *A. amurensis* has an average life span of 2–3 years, with a maximum recorded age of 5 years (NIMPIS 2002).

#### 1.1.3.2 Life habit

*Asterias amurensis* inhabits cool temperate waters. It occurs subtidally, from the near-shore zone down to 200 m (Sutton & Bruce 1996). It is the dominant inshore predator in its native environments in the northern Pacific and is known to go through sporadic population explosions (up to seven individuals per $m^2$), during which time it can cause significant damage to both natural and cultured shellfish beds. *A. amurensis* is an opportunistic generalist predator that consumes a wide variety of prey including many species of mussels, gastropods, clams, crabs, molluscs, ascidians, bryozoans, sponges, crustaceans, polychaetes, fish and echinoderms. It can occur in a variety of soft-sediment, rocky reef and man-made subtidal habitats.

The voracious feeding habit of *A. amurensis* is known to significantly reduce populations of bivalves in soft-sediment assemblages (Ross, Johnson & Hewitt 2002). Native prey species are known to adapt to local predators with novel mechanisms to reduce their predation. However, the Australian scallops *Chlamys asperrima* and *Pecten fumatus* are not able to respond to the presence of *A. amurensis* in the same way they respond to the native seastar *Coscinasterias muricata*. Field and laboratory trials showed that both species of scallop display a positive escape reaction to the presence of the native seastar *C. muricata*. Conversely, none of the *C. asperrima* and only 27% of *P. fumatus* demonstrated a positive escape response to the presence of *A. amurensis* in laboratory trials (Hutson et al. 2005). This lack of escape response to an introduced predator can have significant effects on the survival of native species populations (Hutson et al. 2005).

Adult *A. amurensis* has few predators in either its native or introduced ranges. The orange sun star (*Solaster paxillatus*) in Japan and the Alaskan king crab (*Paralithodes camtschaticus*) have been observed preying on *A. amurensis* in an aquarium. There is anecdotal evidence of large spider crabs feeding on *A. amurensis* in the Derwent estuary (Ling & Johnson 2009), but little is known about potential predators in Australia.

*A. amurensis* has relatively narrow tolerance to changes in salinity and is sensitive to a decrease in salinity (Kashenko 2003). In general, seastars are particularly susceptible to changes in salinity because they lack protective coverings, but they are highly mobile and are able to actively select a more suitable habitat (Kashenko 2003). The tolerance of *A. amurensis* to changes in salinity appears to be slightly different depending on the location of the population. The lower limit of the salinity tolerance for *A. amurensis* was found to be approximately 12 ppt on the east coast of Tasmania, and in Russia, salinity levels lower than 24 ppt instigated negative responses from seastars (Kashenko 2003). Weak substrate attachment and an inability to recover locomotor activity are indicators of responses to decreased salinity.

### 1.1.4 Global and Australian distribution

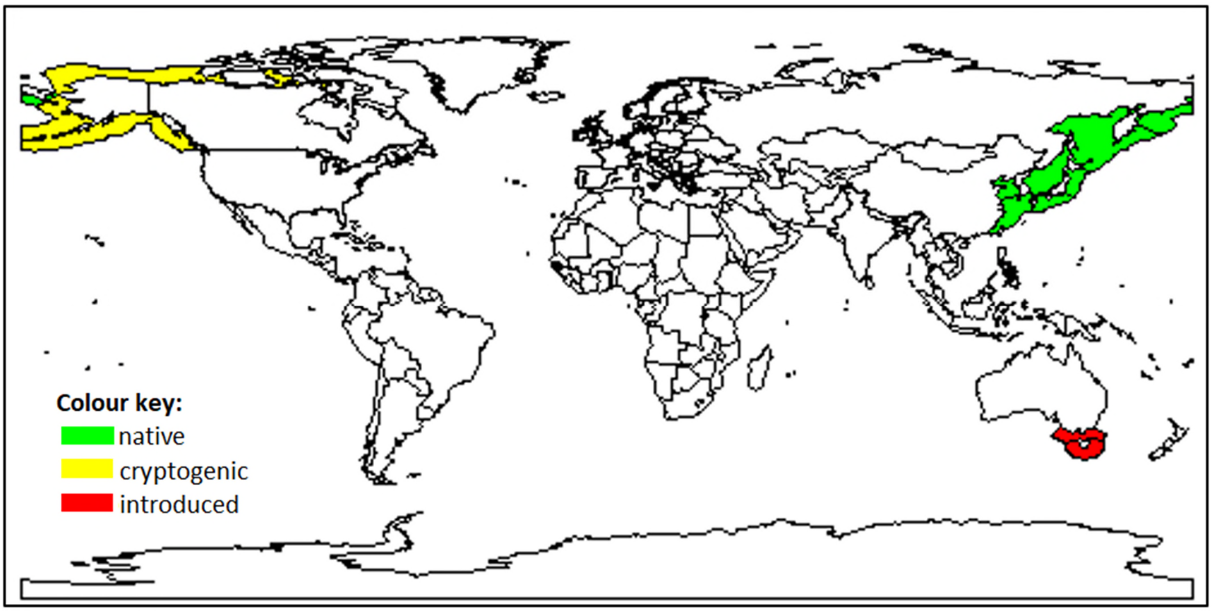
*Asterias amurensis* is native to the north Pacific region, with its natural range extending from China, Korea, Japan and the Kamchatka Peninsula of Russia across the Bering Sea to Alaska (Map 1). However, Russian scientists consider that reports of *A. amurensis* from Alaska and Canada are the result of another accidental introduction (Buttermore, Turner & Morrice 1994).

*A. amurensis* has been present in Tasmania since at least 1986. Specimens recovered from the Derwent estuary in 1986 were initially identified incorrectly as the native seastar, *U. granifera*, but on re-examination in 1992 were found to be *A. amurensis*. In the intervening years, the population had grown to become a dominant component of the benthic fauna in the Derwent estuary. Although the largest populations in Tasmania are still in the Derwent River estuary, *A. amurensis* is now found all along the east coast of Tasmania, down to Southport in the south and Banks Strait at the north-east tip of Tasmania.

In August 1995, an adult *A. amurensis* was caught off Point Cook in Port Phillip Bay. Despite a major effort to find and eradicate *A. amurensis*, only three more adults were found in the next 30 months—one in September 1995, one in August 1996 and another in April 1997. However, in 1998, evidence of a breeding population was found. In January, four juveniles were found off Dromana and by the end of April more than 100 juveniles had been caught in the same area. By February 1999, *A. amurensis* covered about 100 km$^2$ in the eastern and central part of Port Phillip Bay. It remains an abundant component of the benthic fauna in Port Phillip Bay.

In late 2003, *A. amurensis* was found on rocks just outside the entrance to Anderson Inlet at Inverloch, Victoria. Searches located a population just inside the inlet's entrance in March 2004. An emergency response coordinated by the then Victorian Department of Sustainability and Environment (DSE) between March and June 2004 involved intensive searches for, and removal of, *A. amurensis* by teams of divers. Dive surveillance since then has provided few new records of *A. amurensis* at Inverloch, with only two specimens found in December 2004 and one found in February 2005 (Holliday 2005).

**Map 1 Global distribution of *Asterias amurensis***




**Cryptogenic** Unknown origin, may be native or introduced.
Source: NIMPIS 2002

### 1.1.5 Potential impact

*Asterias amurensis* is a generalist, voracious predator that can severely alter benthic assemblages by consuming a large variety and quantity of species. In 1954, an outbreak of *A. amurensis* in Tokyo Bay caused a severe loss of marketable shellfish that cost the industry more than 400 million yen (Kim 1968). Population densities overseas usually subside following major outbreaks. However, in Australia, densities are often maintained at more than seven seastars per m$^2$, particularly in areas where there is an abundant supply of food, such as around wharf piles, shellfish beds and shellfish aquaculture facilities (DSE 2001).

*A. amurensis* is capable of altering habitat and food webs and reducing the abundance of native species that are the basis of commercial and recreational fisheries (Hayes et al. 2005). Snapper and gummy shark fishermen in Port Phillip Bay have reported significant losses of bait to *A. amurensis*; one fisherman reported that, on one occasion, almost all his 200 hooks were lost to *Asterias* on a single deployment (Parry, Werner & Heislers 2003). Tasmanian shellfish farmers routinely report heavy losses of juvenile stock to settling *A. amurensis* that grow at up to three times the rate of other (native) predators (Dommisse & Hough 2004).

This species was most likely introduced to Australian waters from Japan through ballast water some time before 1986 and the population in the Derwent estuary was estimated in 1994 to be more than 30 million (Goggin 1998).

The potential impact of *A. amurensis* on social, economic and environmental categories if the species is not controlled is illustrated in

Table 3.

### Table 3 Categories of potential impact caused by *Asterias amurensis*

| Impact category | Description | Potential impact |
|---|---|---|
| Social amenity | Human health | No |
| Economy | Aquatic transport | No |
| | Water abstraction/nuisance fouling | No |
| | Loss of aquaculture/commercial/recreational harvest | Yes |
| | Loss of public/tourist amenity | No |
| | Damage to marine structures/archaeology | No |
| Environment | Detrimental habitat modification | No |
| | Alters trophic interactions and food-webs | Yes |
| | Dominates/out-competes and limits resources of native species. | Yes |
| | Predation of native species | Yes |
| | Introduces/facilitates new pathogens, parasites | No |
| | Alters bio-geochemical cycles | No |
| | Induces novel behavioural or eco-physical responses | No |
| | Genetic impacts—hybridisation and introgression | No |
| | Herbivory | No |

Source: Hayes et al. 2005

# 2 Pest pathways and vectors

Accidental introduction through ballast water is the most likely means by which *Asterias amurensis* was introduced into Australia before 1986. Today, ballast water regulation both internationally and domestically should reduce this risk significantly.

*A. amurensis* can also be transported locally as free-living juveniles or adults within fouling assemblages and, as larvae, within contained seawater systems. Juveniles can be quite cryptic in fouling assemblages and may be moved by translocation of aquaculture equipment or stock. Table 4 lists the pathways and vectors by which *A. amurensis* can be spread.

### Table 4 Pathways and vectors for *Asterias amurensis*

| Pathway | Description | Vector for spread |
|---|---|---|
| Biocontrol | Deliberate translocation as a biocontrol agent | No |
| | Accidental translocation with deliberate biocontrol release | No |
| Canals | Natural range expansion through man-made canals | No |
| Debris | Transport of species on marine debris (includes driftwood) | No |
| Fisheries | Deliberate translocation of fish or shellfish to establish or support fishery | No |
| | Accidental with deliberate translocation of fish or shellfish | Yes |
| | Accidental with fishery products, packing or substrate | No |
| | Accidental as bait | No |
| Individual release | Deliberate release by individuals | No |
| | Accidental release by individuals | No |
| Navigation buoys, marine floats | Accidental as attached or free-living fouling organisms | Yes |
| Plant introductions | Deliberate translocation of plants species (such as for erosion control) | No |
| | Accidental with deliberate plant translocations | No |
| Recreational equipment | Accidental with recreational equipment | Yes |
| Scientific research | Deliberate release with research activities | No |
| | Accidental release with research activities | No |
| | Deliberate translocation as a biocontrol agent | No |
| Seaplanes | Accidental as attached or free-living fouling organisms | No |
| Vessels | Accidental as attached or free-living fouling organisms | Yes |
| | Accidental with solid ballast (such as with rocks or sand) | No |
| | Accidental with ballast water, sea water systems, live wells or other deck basins | Yes |
| | Accidental associated with cargo | No |

Source: Hayes et al. 2005

*A. amurensis* is frequently taken as by-catch in benthic trawl or dredge fisheries, where the fishing gear contacts the sea floor. It is highly likely to be spread to new locations in fishing operations, within dredges and nets or when discarded during sorting of catch (Dommisse & Hough 2004).

Dommisse and Hough (2004) also suggest that movement of baited fishing gear (such as traps and lines) may be a possible vector for *A. amurensis*.

Vessel biofouling includes all external and internal wetted surfaces, and includes seachests, bilge keels, anode blocks, rudder pins, propellers, shaft protectors, echo sounder transducers and log probes. Although there have been no direct observations of *A. amurensis* on vessel hulls (Dommisse & Hough 2004), it is possible that small juveniles sheltering in heavily fouled areas may have been overlooked. There have been isolated cases of *A. amurensis* found in areas associated with the hull (such as seachests) but the infrequency of these sightings suggests that such occurrences are rare. Slow-moving structures that contain significant biofouling, such as oil rigs and barges, may be more important vectors for the spread of juvenile *A. amurensis*.

The long planktonic life of *A. amurensis* larvae means they may be transported considerable distances by ocean currents. Molecular analysis of specimens obtained from the incursion at Anderson Inlet (Inverloch) suggests that the population was most likely to have been sourced from Port Phillip Bay. Whether this was through planktonic dispersal from Port Phillip Bay or spread of adult *A. amurensis* by human movements is unclear. Nevertheless, populations within Port Phillip Bay and the Derwent River estuary remained relatively contained in each area for long periods following discovery, presumably due to entrained water circulation within the embayments.

# 3 Policy and rationale for incursion response

The policy and rationale for an incursion response is based on the generic policy for incursion response to marine pests in Australian waters, the control or eradication strategy for *Asterias amurensis*, the policy on decision points and the policy on funding of operations and compensation. This chapter is an overview of marine pest emergency procedures and policy.

## 3.1 Generic policy for incursion response to marine pests in Australian waters

The National Environmental Biosecurity Response Agreement (NEBRA) establishes national arrangements for responses to nationally significant biosecurity incidents when there are predominantly public benefits. In the absence of a marine pest-specific deed, responses to marine pest incidents can fall under the NEBRA. The NEBRA provides a mechanism to share responsibilities and costs for a response when eradication is considered feasible and other criteria are met. The Biosecurity Incident Management System provides guidance on policies and procedures for the management of biosecurity incident responses, including responses to marine pest emergencies within Australian waters.

### 3.1.1 Commonwealth, state and territory authority responsibilities

Lead agencies in the response to a marine pest emergency must collaborate with CCIMPE in developing a National Biosecurity Incident Response Plan (NBIRP) as required under the NEBRA. CCIMPE will review the NBIRP and provide advice to the National Management Group (NMG), which will determine whether national cost-sharing arrangements should be activated. If the NBIRP and cost-sharing arrangements are approved, CCIMPE will help an affected jurisdiction implement an NBIRP. State coordination centres must be established with responsibility for strategically managing a marine pest incursion and for ensuring that community and/or industry involvement and communications are in place.

Depending on the circumstances, a local control centre with responsibility for managing field operations in a defined area may be established to enable an efficient and effective operational response. While close communication between a state coordination centre and a local control centre is imperative for effective conduct of any emergency response, it is important that strategic management (state coordination centre) and operational management (local control centre) roles be kept separate to optimise effective decision making and implementation during a national biosecurity incident response.

When a national coordination centre is established to help manage concurrent incursions in more than one jurisdiction, national coordination will be effected through consultation with CCIMPE representatives and relevant industry and community sector organisations, as appropriate.

#### 3.1.1.1 Consultative Committee on Introduced Marine Pest Emergencies

CCIMPE provides national coordination for managing marine pest emergencies and comprises senior representatives from each Australian jurisdiction with coastal borders (the Australian Capital

Territory is not represented). CCIMPE is the national technical body that advises NMG whether an incursion by an introduced marine pest represents a marine pest emergency (in a national context), and coordinates the national technical response. CCIMPE also makes recommendations on possible stand-down phase activities (such as monitoring).

### 3.1.2 Emergency response stages

Management of a marine pest emergency of national significance has four phases of activation:

- investigation phase
- alert phase
- operations phase
- stand-down phase.

The first two phases, while detailed separately in the rapid response manuals, may be run concurrently, as outlined in the Biosecurity Incident Management System. Progression from one stage to the next depends on the nature of the emergency and available information.

Not all detections of marine pests will initiate a response involving all four phases and certain responses (such as detection of marine pests on vessels) may involve truncated responses.

#### 3.1.2.1 Investigation phase

The investigation phase is in effect when relevant authorities are investigating a reported detection of a marine pest. The initial report of a suspected marine pest may come from port surveys, in water vessel inspections, slipway operators, fishermen, members of the public and routine field and surveillance activities.

A notifying party must advise the CCIMPE of a suspected outbreak of a marine pest within 24 hours of becoming aware of it to be eligible for cost sharing under the NEBRA. When making a preliminary assessment, the notifying party may decide that a notification is likely to trigger a marine pest emergency alert when:

- the species detected is likely to be of national significance (Schedule 2 of the NEBRA) based on available data
- the description matches a species represented on the Australian Priority Marine Pest List (APMPL) that is either not present in Australia or, if it is present, the detection represents a new outbreak beyond the known range of established populations of the species in Australia. All APMPL species have been assessed to be of national significance.
- the species detected has a demonstrable:
  - invasive history
  - impact in native or invaded ranges on the economy, the environment, human health or amenity
- the species detected is inferred as likely to have major impacts in Australia based on available data and characteristics of Australian environments and marine communities
- the suspected outbreak cannot be managed through pre-existing cost-sharing arrangements

- one or more relevant translocation vectors are still operating.

If the investigation indicates that a marine pest emergency is highly likely, the notifying party will inform the reporting point and will direct implementation of the alert phase.

Given that *A. amurensis* is already established in Australia and is on the APMPL, a suspected detection outside its current range will represent a possible range extension and trigger an emergency alert. If the subsequent investigation concludes that the situation does not constitute a marine pest emergency, the notifying party will inform CCIMPE and the emergency alert will be cancelled.

#### 3.1.2.2 Alert phase

The alert phase is in effect while confirmation and identification of a suspected marine pest is pending, and an incident management team is assessing the nature and extent of the suspected incursion. During the alert phase:

- all relevant personnel are to be notified that an emergency alert exists in the affected jurisdiction
- an incident management team is appointed to confirm the identification of the suspected pest and to determine the likely extent of an incursion
- control measures are initiated to manage the risk of pest spread from affected sites (for example, operational boundaries of restricted areas are established for potential vectors)
- the findings of an emergency investigation are communicated to CCIMPE and NMG to enable a decision to be made on whether to proceed to the operations phase.

If an emergency investigation shows there is no incursion by a marine pest of concern or there is an incursion but it is unlikely to be eradicable, the notifying party will:

- ensure interim containment measures are implemented to minimise the risk of pest translocation from any infested waterway
- provide a situation report to the CCIMPE Secretariat for the information of CCIMPE representatives and request a CCIMPE teleconference to enable consultation with all jurisdictions
- on reaching agreement from CCIMPE, request that the transition to management phase (when there is a confirmed incursion by a marine pest of concern but eradication is not considered feasible) or stand-down phase be implemented (when investigation shows there is no incursion by a marine pest of concern).
- Ensure documentation relevant to the decision-making process is maintained and filed as a 'negative marine pest emergency alert' (when investigation shows there is no incursion by a marine pest of concern) or a 'non-eradicable marine pest emergency alert' (when there is a confirmed incursion by a marine pest of concern but eradication is not considered feasible).

If the emergency investigation shows there is an incursion by a marine pest of concern and it is potentially eradicable, the notifying party will:

- ensure appropriate emergency containment measures are continued to minimise the potential for pest translocation, both from and within any infested waterway
- provide a situation report and an NBIRP plan to the CCIMPE Secretariat for urgent consideration by CCIMPE representatives and request a CCIMPE teleconference to enable consultation with all jurisdictions
- following CCIMPE endorsement, submit the NBIRP to NMG for consideration of national cost-sharing arrangements to help resource a national biosecurity incident response.

#### 3.1.2.3 Operations phase

The Operations phase of an emergency response commences when the marine pest emergency is confirmed by agreement through the NMG forum and activities under a response plan are implemented. During the operations phase of a national biosecurity incident response:

- all relevant personnel and agencies should be notified that a national biosecurity incident response is being undertaken in the affected jurisdiction
- a standing committee on conservation and a local control centre should be established, if necessary
- control measures initiated in the alert phase should remain in place to manage the risk of pest spread from affected sites
- measures to eradicate the pest from infested sites should be implemented
- information from infested sites about the pest and the progress of operations should be collected, documented and analysed to enable progress of a national biosecurity incident response to be monitored
- expenditure associated with all eligible costs under cost-sharing arrangements should be documented
- regular situation reports should be communicated to the CCIMPE forum
- a decision should be made, when appropriate, on when to proceed to the stand-down phase.

#### 3.1.2.4 Stand-down phase

The stand-down phase is in effect when, following appropriate consultation between the affected jurisdiction and CCIMPE, all agree that there is no need to progress or continue with a national biosecurity incident response. During the stand-down phase:

- a systematic approach to winding down operations must be taken to ensure operational effectiveness is not jeopardised
- all personnel, agencies and industry contacts involved in the emergency response are to be notified of the stand down.

The stand-down phase must commence once operational objectives have been achieved, or otherwise in accordance with advice provided by CCIMPE and agreed by NMG. The advice that an emergency eradication operational response is no longer needed must be communicated to the affected jurisdiction.

## 3.2 Control and eradication strategy for *A. amurensis*

*Asterias amurensis* is present in large numbers in the Derwent Estuary, and has been recorded along the east coast of Tasmania from Recherche Bay in the south to Banks Strait in the north. It is also well established in Port Phillip Bay, Victoria. While it has been recorded from Anderson Inlet, Inverloch, it is currently considered to have been eradicated from there. *A. amurensis* is considered absent from all other Australian waters. Any reports of the suspected presence of *A. amurensis* in Australian waters should initiate the investigation phase of an emergency response.

The methods used to control incursion of *A. amurensis* in Australian waters depend on the location and size of the outbreak. If the emergency investigation revealed an incursion by *A. amurensis* that was potentially eradicable, the Incident Manager would prepare an NBIRP and forward it to CCIMPE for urgent consideration.

The options for controlling an incursion by *A. amurensis* in Australian waters are:

1) Eradication of the pest from the infested area.
2) Containment, control and zoning with the aim of containing the species and slowing its further spread to other areas.

Eradication is unlikely if initial investigations show the species is widely established in open marine environments. Each control option involves a combination of strategies, such as:

- establishing declared areas to define zones where the pest is present or suspected to occur, and where emergency management operations are to be implemented
- quarantining and restricting or controlling movement of potential vectors, such as submersible equipment, vessels, marine organisms (fauna and flora) and ballast water in declared areas to prevent spread of the pest
- decontaminating potential vectors for the pest, including vessels, aquaculture stock and equipment, maritime equipment, and water that may contain larvae of the pest
- treating established populations on natural and artificial habitats in the infested area
- delimiting and tracing surveys to determine the source and extent of the incursion
- surveillance and monitoring to provide proof of freedom from the pest.

## 3.3 Policy on decision points

The policy on decision points includes proof of eradication and decisions to stand down eradication or control operations.

### 3.3.1 Proof of eradication

Proof of eradication requires a robust and intensive monitoring program during the operations phase of the response. During the operations phase, the purpose of the monitoring program is to detect new outbreaks of *Asterias amurensis* for treatment and to determine the efficacy of the treatment procedure. This information can be used to refine and direct treatment.

Monitoring should also continue at sites potentially at risk of infestation. A decreasing trend in the number of new, untreated clusters of *A. amurensis* detected over time in the infested area is evidence of the effectiveness of the control measures.

### 3.3.2 Stand down eradication or control operations

The optimal time to stand down monitoring, eradication and control operations is a trade-off between the costs of maintaining emergency operations, including ongoing surveys (Cs), the cost of escape (including likely impacts) if eradication is declared too soon (Ce), the probability of detecting the pest species given it is present (q) and the annual probability the species remains present (p). This rule of thumb can be used to calculate the optimal number of surveys:

$$n^* = \frac{\ln\left\{\dfrac{-C_s}{C_e \ln(r)}\right\}}{\ln(r)}$$

Where r = p(1 – q) is the probability the pest is not detected but is still present in the survey area. See Regan et al. (2006) for guidance on calculating this decision point.

## 3.4 Policy on funding of operations and compensation

CCIMPE will help determine whether an incursion is likely to be eradicable and when national cost-shared funding under the NEBRA should be sought. Cost sharing must be agreed by NMG.

As detailed in the NEBRA, parties will share the eligible costs of emergency eradication responses as follows:

- a 50% share from the Australian Government
- a 50% share collectively from the states and the Northern Territory
  - this is calculated for each jurisdiction based on the length of coastline potentially affected by the species, and their respective human populations
  - only jurisdictions affected or potentially affected by the pest or disease are required to contribute.

NMG may commit up to $5 million (in annual aggregate) towards the eligible costs associated with an agreed national biosecurity incident response. If this $5 million is exceeded in any one financial year, NMG must seek ministerial approval from all parties to continue activities and/or begin new emergency responses.

Private beneficiary contributions to a response will be considered by NMG on a case-by-case basis where there is one or more private beneficiary and no existing arrangements.

# 4 Principles for containment, control and eradication

Eradication of incursions by *Asterias amurensis* depends on early detection and immediate action. The limited tools available for removal of *A. amurensis* populations and its potentially large reproductive output means eradication is most likely to be successful where the population is relatively small, aggregated and occurs in shallow and partially or fully enclosed waterways. The chances of success will be greatest if the incursion is detected before the population has reached reproductive maturity.

Since *Asterias* is an externally fertilised broadcast spawner, the density of reproductively mature adults is critical in determining the proportion of eggs fertilised. Population modelling for *A. amurensis* has shown that sheltered waterways are also likely to provide the environmental conditions under which high-density populations can rapidly grow if spawning occurs. Sites that have long retention times (that is, lagoons and estuaries with narrow entrances or very large volumes) are most likely to retain larvae that will develop into a high-density population. Sites where space is limited, so that high densities are achieved with fewer adults, are also at high risk. These sites will produce more larvae due to increased fertilisation success than sites with the same numbers but spread over a larger area. In open coastal waters with moderate-to-high water exchange, larvae may be dispersed over a wide area. Where monitoring surveys indicate that an infestation is widespread, detection of all individuals will be difficult and it is unlikely that eradication will be successful. However, in these circumstances, high density populations are likely to take longer to build up because adults are highly dispersed, reducing fertilisation success (Bax et al. 2006).

Characteristics of this species and the pathways by which it is spread make it difficult to eradicate. These include:

- high fecundity, with a long-lived planktonic larval stage (of two to four months) that can be dispersed over large distances by water currents
- ability to recruit and survive as juveniles or adults in confined wetted spaces, including vessel seachests, water intake pipes and bilge lockers, making detection difficult
- presence in estuarine environments, which can be turbid, making detection difficult.

The basis of eradication is rapid, effective quarantine of the infested area and any potentially contaminated vectors, and elimination of the pest where it is found.

The *A. amurensis* incursions in Port Phillip Bay and Anderson Inlet, Inverloch, were characterised by low initial densities. In Port Phillip Bay, the first specimens located were adults that occurred at a very low density and were dispersed across a large area of the bay, making it difficult to detect all potentially reproductive individuals. Eradication attempts were unsuccessful either because *A. amurensis* had spawned before being found or because other reproductively mature aggregations were not detected, despite a major effort to locate them. In Inverloch, *A. amurensis* was predominantly aggregated over a sponge-covered reef just inside Anderson Inlet. The relatively small area over which the population was distributed, and the fact that most individuals detected appeared to be reproductively immature and from a single cohort, meant eradication was feasible.

The closure of Henderson Lagoon (on the east coast of Tasmania) to the sea, by a sand bar created by a large swell, provided an opportunity for an eradication attempt of *A. amurensis*. The exercise proved that it was capable of surviving decreasing salinity in a closed estuary for six months. Trapping was largely ineffective, although scientists and locals manually removed a significant number of organisms. When the sandbar blocking the estuary was finally removed, the last remaining *A. amurensis* were found to be dead and decaying. It is thought this was a result of a decrease in the salinity at the bottom of the estuary and a breakdown of the stratification (McManus & Proctor 2001; Proctor & McManus 2001).

These examples suggest that early detection, a relatively confined incursion and ease of detection are key elements if eradication is to be successful.

## 4.1 Methods for preventing spread of the organism

Methods used to prevent the spread of the organism are quarantine and movement control, and treatment for decontamination of infested vectors.

### 4.1.1 Quarantine and movement controls

Quarantine and movement controls include an investigation phase, an alert phase and an operations phase.

#### 4.1.1.1 Investigation phase

When the presence of *Asterias amurensis* is suspected in an area but a marine pest emergency has not yet been confirmed (see section 3.1.2.1), the notifying party should, when feasible, take steps to limit the spread of the suspected pest from the investigation site or area by initiating voluntary restrictions on movement of potential vectors. This may involve notifying relevant port authorities, marina operators, industry associations and vessel owners in the suspect site about the investigation into a possible marine pest emergency. Cooperation should be sought from these stakeholders to stop, restrict or inform the notifying party of movement of vectors from the site. Compliance with voluntary movement controls may be enhanced by distribution of appropriate public awareness materials about the pest.

The investigation phase should attempt to identify all potential vectors present at the site and their location. Possible vectors for the spread of *A. amurensis* are described in chapter 2.

#### 4.1.1.2 Alert phase

If the initial investigation finds that *Asterias amurensis* is highly likely to be present (see section 3.1.2.2), the findings should be communicated to CCIMPE for consideration of the appropriate course of action to manage the risk of spread from affected sites. The incident management team must ensure appropriate measures are implemented. These could include:

- restrictions on movement of potential vectors, such as submersible equipment, fishing gear, vessels, marine organisms (fauna and flora) and ballast water into and out of suspect sites
- restrictions on benthic fishing, including bottom trawling, dredging, weighted line fishing and use of baited traps in potentially affected areas

- controlling movement of people (such as property owners, scientists, tourists) into or out of the suspect sites, as appropriate; this may include police involvement
- a hotline phone number for reported sightings of the pests and inquiries from affected parties
- tracing potential vectors that have left the site
- redirecting vessels that have already left the site to appropriate sites for inspection and/or decontamination, if appropriate
- requiring fishing vessels that have left the site to retain all seastar bycatch and shell debris until it can be inspected and cleared
- notifying and, where appropriate, consulting relevant experts.

#### 4.1.1.3 Operations phase

The operations phase will be guided by whether eradication of the marine pest of national concern is feasible or not feasible.

##### Eradication not feasible

If investigation reveals an incursion by *A. amurensis* that is unlikely to be eradicable, interim containment measures (to prevent translocation of a pest of concern from any infested waterway) should be implemented to minimise the risk of the pest being spread from the infested area. A stand-down phase may be entered either directly from the alert phase or from the operations phase when CCIMPE and NMG agree there is no need to initiate a national biosecurity incident response.

##### Eradication feasible

If investigation reveals a potentially eradicable *A. amurensis* incursion, quarantine and associated movement restrictions can be implemented.

Quarantine restrictions require establishing specified areas:

- infested area—all or part of a waterway in which a marine pest emergency is known or deemed to exist (pending confirmation of pest identification)
- dangerous contact area—an area close to an infested area in which a pest has not been detected but, due to its potential for infestation, will be subject to the same movement restrictions as an infested area
- suspect area—an area relatively close to an infested area that will be subject to the same movement restrictions as an infested area (pending further investigation)
- restricted area—area around an infested area that is subject to intensive surveillance and movement controls on potential vectors[2].

---

[2] Note that the legislative ability and scope of powers to establish biosecurity restricted areas and control areas will depend on the biosecurity legislation that is applicable within the relevant jurisdiction.

- control area—defined area surrounding a restricted area in which biosecurity conditions apply to the entry or exit of potential vectors or specified risk items [2].

Similar terminology is applied to potentially affected vectors within each area. For example, a vessel within a dangerous contact area would be classified as a 'dangerous contact vessel'; a vessel within an infested area would be classified as an 'infested vessel'.

The extent of each specified area for *A. amurensis* should be determined based on:

- an initial delimiting survey of the area (section 5.3)
- an evaluation of the length of time the species has been present and whether it has reproduced; this would be based on the size and distribution of the animals in the infested area, the number of cohorts apparent and, when possible, examination of reproductive tissue
- the strength and distribution of directional or tidal currents
- expert advice.

Movement restrictions include limiting:

- the movement of vessels, immersed equipment, aquaculture stock or equipment and other vectors for biofouling
- fishing activities within the control area
- the uptake or movement of ballast water or other water from within the control area where appropriate controls are not in place.

Implementation of restrictions will be a dynamic process, determined by the location and extent of infestation and whether the aim is to eradicate the pest or to control its spread. Some restrictions may be deemed impractical or unnecessary in a particular circumstance, but others will be critically important to eradication or control.

### Restricted Area Movement and Security Unit

The Restricted Area Movement and Security Unit of the Operational Pest Control Centre is responsible for controlling movement of goods, submersible equipment, vessels, water and other vectors including people into, within and out of the restricted area as appropriate to minimise the potential for pest spread. The unit's main duties are to:

- issue movement permits to the public
- establish and operate road and water checkpoints in the restricted area, including liaison with state transport authorities, water authorities, police and local government
- coordinate movement and security activities across infested sites
- maintain registers of all movements (in restricted and infested areas), permits issued and staff deployed.

### Experience of movement controls

The emergency response to the incursion by the black striped false mussel, *Mytilopsis sallei*, in Cullen Bay Marina (Darwin) in 1999, used a combination of the powers in the *Fisheries Act 1988* (NT) and the *Quarantine Act 1908* (Cth) (superseded by the *Biosecurity Act 2015)* to impose sufficient quarantine measures to limit the spread of the species. The *Biosecurity Act 2015* can be used in the absence of appropriate state or territory legislative powers and may be used in certain circumstances, including directing conveyances[3]:

- into port
- to not enter a port and to obey further instruction
- to undergo a treatment action the Incident Manager deemed necessary. The Australian Director of Biosecurity (or their delegate) can authorise State and Territory officers as biosecurity officers under the *Biosecurity Act* which will enable certain actions to be undertaken in a biosecurity response. All actions taken against a conveyance should only be taken in relation to those identified as being at risk of spreading the invasive species (Ferguson 2000). Guidelines for using the *Biosecurity Act 2015* are in Appendix A. The Biosecurity Act is only intended to be used if there is no appropriate State and Territory legislation that provides appropriate powers necessary for the response, aside from ballast water which is entirely covered by the Biosecurity Act. A provisional list of other Commonwealth and state powers for intervention and detention of vessels is in Appendix B.

Each state and territory should consider enacting relevant fisheries or other legislation to prevent or control fishing within a control area, and prevent or control translocation of stock and equipment from within it. Any requested movement of fishing gear or aquaculture stock or equipment should be subject to risk assessment consistent with procedures outlined in the National Policy Guidelines for the Translocation of Live Aquatic Organisms (Department of Agriculture 2020). All potentially infested fishing gear, aquaculture equipment or stock should be treated and inspected before removal from the control area.

### 4.1.2 Surveillance for high-risk vectors

In the event of an emergency marine pest response, movement controls on potential vectors and pathways will be easier to manage if efforts can be targeted at vectors that pose the greatest risk of spread.

All ballasted vessels and other vectors that have been within an infested area or dangerous contact area during the time the pest is known or suspected to have been present should be considered at high risk of transporting the pest. Vessels, oil rigs, barges and other moveable structures that have been present in suspect, restricted or control areas, that have marine fouling on them, should also be treated as high risk.

Non-ballasted vessels and other small craft that have minimal fouling and small internal water systems should be considered at moderate risk of transporting *Asterias amurensis*. All forms of benthic fishing (including baited line fishing, baited and non-baited traps and nets, trawls and dredging) should be considered high risk. All equipment from these forms of fishing should be

[3] Under the *Biosecurity Act* the definition of conveyances includes vessels and floating structures

inspected and treated before removal from the control area. Stock and equipment from open system or semi-enclosed shellfish aquaculture should be considered at high risk of infestation and subject to inspection and treatment. Stock and equipment from other forms of aquaculture should be considered at moderate risk and subject to inspection.

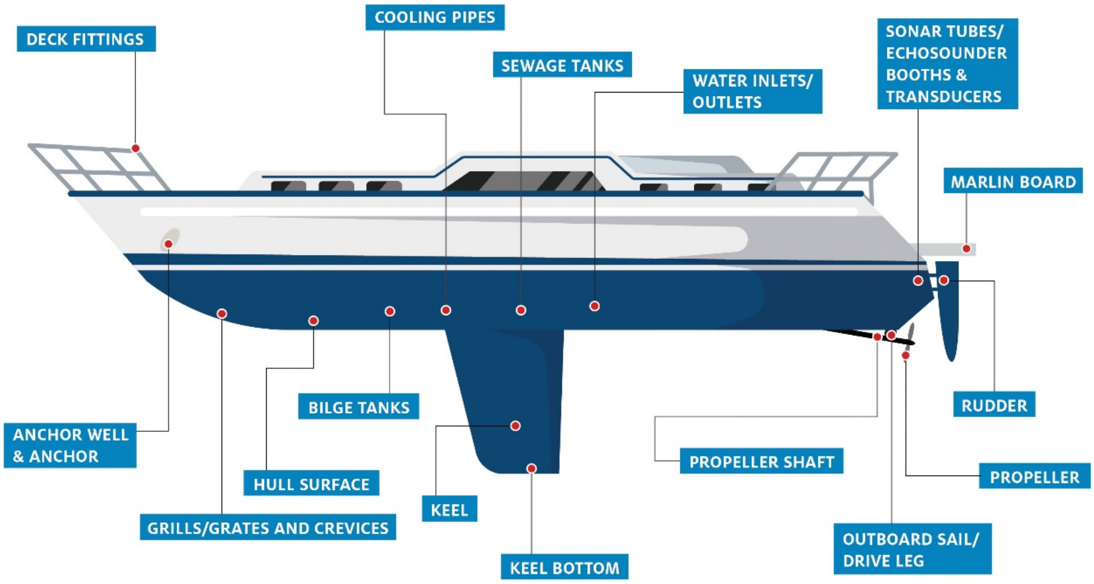
Where resources allow, all vessels and potential vectors within the control area should be inspected for signs of the pests. Medium-risk vectors should be required to remain within the control area until they can be inspected and declared free of the pest.

Divers or Remotely Operated underwater Vehicles (ROVs) should perform in-water inspection of vessels using a standardised search protocol. Biofouling is likely to be greatest in wetted areas of the vessel that are protected from drag when the vessel is underway and/or where the antifouling paint is worn, damaged or was not applied.

For vessels smaller than 25 m in length (Figure 2), particular attention should be given to inspecting:

- rudder, rudder stock and post
- propellers, shaft, bosses and skeg
- seawater inlets and outlets
- stern frame, stern seal and rope guard
- sacrificial anode and earthing plate
- rope storage areas and anchor chain lockers
- ropes, chains or fenders that had been left over in the water
- keel and keel bottom
- sounder and speed log fairings.

**Figure 2 High-risk niche areas for inspection of biofouling on vessels less than 25 metres**




For vessels larger than 25 m in length (Figure 3), additional high-risk niche areas include:

- dry docking support strips (DDSS)
- seachests and gratings
- sonar tubes
- bow thrusters
- keel and bilge keels
- ballast tanks and internal systems.

**Figure 3 High-risk niche areas for inspection of biofouling on vessels greater than 25 metres**

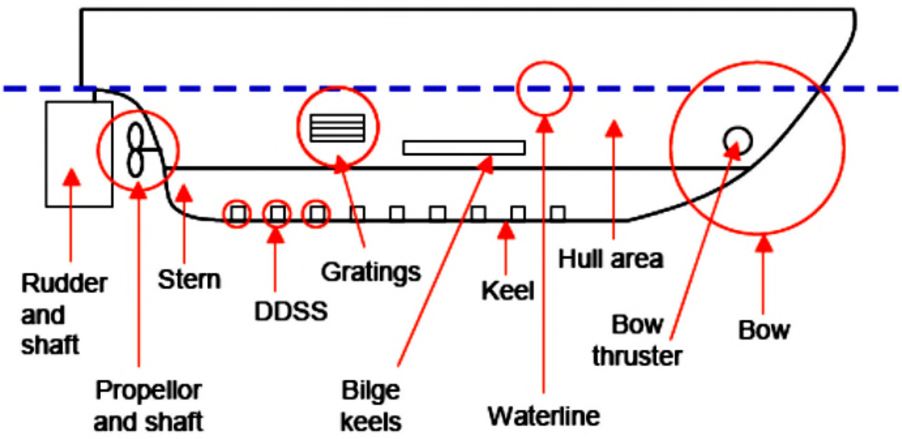



Image: Floerl 2004

Divers can inspect interior spaces and crevices (such as seachests, water intakes or outlets) using endoscopes.

Surveillance for larvae in ballast water taken up within the control area may be done by screening water samples from the ballast tanks using molecular probes developed specifically for *A. amurensis* (Bax et al. 2006). While the probes are highly specific for *A. amurensis*, limited mixing of ballast water on board vessels and the difficulties of extracting representative samples from the tanks mean verification of freedom from infestation is extremely difficult. In these circumstances, the most risk-averse strategy is to prevent uptake of ballast water within the control area and to prevent discharge of potentially infested water in environments where *A. amurensis* could possibly survive.

All high-risk and medium-risk vessels that have recently left a control area should be contacted immediately. If they have not entered another port or marina they should be encouraged to remain at sea, no closer than 1.5 nautical miles to the nearest land until inspection and/or quarantine arrangements can be made. Biosecurity risks detected before or during this inspection must be dealt with before the vessel can be brought further inshore. Where the vessel has entered another port or coastal area, it should be inspected immediately and, if signs of the pest are present, the vessel should be directed for treatment, a back tracing of the vessel's itinerary be done and surveys undertaken of the anchorages it has visited.

### 4.1.3 Treatment methods for decontaminating infested vectors

Treatment methods differ depending on the type of area in which the infestation occurred. It could have been found in ballast water, on vessels or on equipment and marine organisms.

Table 5 summarises management recommendations for different types of vectors.

## Table 5 Management recommendations for different types of vectors

| Potential vector | Suggested management |
| --- | --- |
| International and domestic yachts and other vessels smaller than 25 m | Clean external submerged surfaces<br>Treat internal seawater systems<br>Manage ballast water<br>Remove from the control area once cleaned |
| Domestic fishing vessels, ferries, tugs, naval vessels | Clean external submerged surfaces<br>Treat internal seawater systems<br>Manage ballast water |
| Merchant vessels larger than 25 m departing for other Australian destinations | Manage ballast |
| Merchant vessels larger than 25 m departing for international waters | Inspect and (where possible) clean external submerged surfaces<br>Treat or seal internal seawater systems<br>Manage ballast water |
| Recreational craft (such as dinghies, jet-skis, kayaks, outboard motors) | Clean external submerged surfaces<br>Clean and dry internal seawater systems<br>Educate users and service agents of risk |
| Fishing gear and nets | Clean and dry on removal from area<br>Educate users of risk |
| Aquaculture stock (fouled) | Remove from infested area and destroy |
| Aquaculture equipment (fouled) | Remove from infested area<br>Clean thoroughly by high pressure (greater than 2,000 psi) water blasting<br>Immerse in copper sulphate solution (4 mg/L) or liquid sodium hypochlorite (200–400 ppm) for 48 hours<br>Rinse in seawater and air dry |
| Buoys, pots, floats | Clean and dry<br>Restrict removal from the control area<br>Educate users on risks |
| Water, shells, substratum, live hard-shelled organisms from the control area (such as aquaria, bait) | Restrict removal from the control area<br>Educate users on risks |
| Flotsam and jetsam | Remove from water/shoreline<br>Dry prior to onshore disposal<br>If possible, use barriers to prevent escape from infested area |
| Fauna (such as birds, fouled crustacean) | Verify the importance of the vector during delimitation surveys |
| Stormwater pipes, intakes | Clean<br>Where possible, seal until stand down of emergency response |

Source: Bax et al. 2002

#### 4.1.3.1 Ballast water

In the event of an emergency response, all ballast water sourced from the area would be considered high-risk to the Australian marine environment. The *Biosecurity Act*, which implements the International Convention for the Control and Management of Ship’s Ballast Water and Sediments (Ballast Water Convention) together with the *Biosecurity (Ballast Water and Sediments)*

*Determination 2017* (Ballast Water Determination), prohibits discharge of ballast water anywhere within Australian seas[4], subject to certain exceptions.

All vessels that contain ballast water will need to be appropriately managed according to the Australian Ballast Water Management Requirements. This includes via an approved method of ballast water management, or disposed of safely, such as through an approved ballast water reception facility. If *Asterias amurensis* is present in an area, steps can be taken by the Department of Agriculture to ensure no low-risk exemptions to discharge ballast water would be granted under section 23 of the Ballast Water Determination.

Since the Ballast Water Convention has come into effect, certain ships are no longer allowed to manage ballast water through exchange. These vessels are required to install acceptable ballast water management systems to ensure appropriate treatment of ballast water on-board. These systems eliminate harmful pests from ballast water by using methods such as UV treatment or chlorination. Vessels that are allowed under legislation to meet ballast water management requirements through exchange (subject to certain exemptions), would be required to conduct ballast water exchange outside Australia's 12 nautical mile territorial sea limit. Additional measures may need to be investigated where vessels utilise ballast water exchange and operate exclusively within a declared Same Risk Area, detailed within the *Biosecurity (Ballast Water Same Risk Area) Instrument 2017*.

Operators may choose to retain high-risk water within a ballast water tank if there is no intention to discharge the water in Australian seas. However, carrying high-risk ballast water into Australian seas is strongly discouraged, as a vessel's itinerary may change, or discharge may be necessary in the case of safety or pollution considerations.

### Vessels departing for international destinations

Vessels leaving the control area for destinations outside Australia's territorial waters should be notified of the risk and required to exchange ballast water sourced from the control area in oceanic waters, outside 200 nautical miles at depths greater than 200 m, as specified by the International Maritime Organization (IMO) International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (Ballast Water Management Convention). Permission should not be given for discharge of high-risk ballast within the 12 nautical mile limit. Options for oceanic exchange of ballast water are described in the Australian Ballast Water Management Requirements (Department of Agriculture 2017) and are consistent with the IMO's Ballast Water Management Convention Guidelines for Ballast Water Exchange.

[4] Under the Biosecurity Act, the definition of Australian seas changes depends on the Administration (the country's flag under which the vessel is registered) of the vessel. For Australian or foreign vessels whose Administration is party to the Ballast Water Convention, Australian seas is waters within the outer limits of Australia's exclusive economic zone (EEZ) (200 nautical miles from the territorial sea baseline). For other vessels, Australian seas is the waters within the outer limits of the territorial seas of Australian (12 nautical miles from the territorial sea baseline).

### Vessels departing for Australian destinations

When possible, vessels travelling to other Australian ports should be encouraged to exchange ballast sourced from the control area in oceanic waters or treat it using an approved on-board ballast water management system. Australian law prohibits discharge of high-risk ballast water anywhere inside Australia's territorial waters (12 nautical mile limit). To avoid discharging high-risk domestic ballast water, the ship may elect to hold the ballast water on-board or transfer it from tank to tank within the ship. This is an acceptable way of managing ballast water risk. However, ships' masters should ensure that, when using this method, they have carefully considered their cargo plans to negate any need to discharge any high-risk ballast water within Australian ports.

Lifecycle modelling of *A. amurensis* within Australian waters suggests it is unlikely to be able to complete its lifecycle and survive any further north than 30 °S (Hayes et al. 2007). Consideration should be given to whether ballast water sourced from a control area should be allowed to be discharged in locations north of this estimated survival threshold.

The IMO's Ballast Water Convention came into effect in 2017, and ballast water management systems are now an accepted alternative to ballast water exchange. These systems eliminate harmful pests from ballast water by using methods such as filtration, UV treatment, electrolysis, active substances and cyclonic separation.

#### 4.1.3.2 Biofouling of vessels and other possible vectors

Mechanical removal of biofouling on vessels includes land-based treatment, internal seawater systems and various in-water treatments.

### Land-based treatment

Because juvenile *Asterias amurensis* may inhabit internal piping and water intakes and may be found among biofouling, they may not be readily detected underwater. Therefore, haul-out of vessels and other non-permanent structures (such as moorings, pontoons, ropes) for inspection and treatment on land is the preferred option for decontamination. This may only be possible for vessels smaller than 25 m in length where suitable haul-out or dry-dock facilities are available within or in close proximity to the control area. Larger vessels may need to be inspected and treated in the water.

High pressure water-blasting (pressures of 2,000 psi or greater) of external surfaces with cold or heated water may successfully remove large biofouling and any seastars present. Care should be taken to treat the niche areas identified in Figure 2 and Figure 3 and any seawater entry points. Cleaned vessels should be left to dry on the hard stand for at least seven days (Gunthorpe et al. 2001).

### Internal seawater systems

Internal seawater systems should be cleaned to the greatest extent possible with:

- 5% (by volume) industrial detergent (Conquest or Quatsan) in water (preferably fresh) for 14 hours (Lewis & Dimas 2007)
- chlorine at a concentration of 24 mg/L for 90 hours (Bax et al. 2002)
- copper sulphate solution at a concentration of 1 mg/L for 38 hours (Bax et al. 2002).

The Incident Manager may approve other treatments. Alternative treatments (such as use of hot water or maintaining freshwater throughout internal systems for at least three days) may be acceptable only if it can be guaranteed that the required temperatures are met throughout the system for the required time (Gunthorpe et al. 2001).

There is a risk that any *A. amurensis* dislodged during haul-out or cleaning of a vessel may remain viable and could start a new population if returned to the sea. The Incident Manager must approve haul-out facilities used for decontamination. Such facilities should be fully contained so material removed from vessel hulls cannot return to the marine environment by any means, including direct disposal, run-off or aerosol drift. All macro (greater than 1 millimetre) particles removed from vessels cleaned out-of-water should be retained and disposed of in landfill (or as biohazard material if appropriate). All liquid effluent (runoff) from out-of-water vessel water blasting or cleaning should be collected for treatment in a liquid effluent treatment system.

Woods et al. (2007) provide guidance for identifying vessel cleaning facilities suitable for removing marine pests. Approved facilities should also comply with relevant state requirements for waste containment and disposal from slipways, boat repair and maintenance facilities.

High-pressure water blasting followed by prolonged (more than 5 days) aerial exposure may also be used to treat other fouled structures removed from an infested area (such as mooring blocks, pontoons, floats, fenders). Materials such as ropes, with fine interstices that may be protected from the blasting and that can retain moisture, should be treated chemically or be disposed of to landfill.

### In-water cleaning

The Anti-fouling and in-water cleaning guidelines (2015) state that where practical, vessels and moveable structures should be removed from the water for cleaning, in preference to in-water operations. When removal is not economically or practically viable, the guidelines accept in-water cleaning as a management option for removing biofouling, provided risks are appropriately managed.

Applicants who wish to perform in-water cleaning in Australian waters should familiarise themselves with the principles and recommendations contained in the guidelines. In Commonwealth waters, applicants should first check their obligations under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). If the activity does not need to be referred under the EPBC Act, then applicants should self-assess their activity using the decision support tool in Appendix A of the Anti-fouling and in-water cleaning guidelines (2015). Applicants who wish to perform in-water cleaning in state or territory waters should contact the relevant agency in each state or territory jurisdiction for advice.

### Wrapping and encapsulation

Wrapping and encapsulation of the submerged surfaces of vessels using impermeable barriers, such as polyethylene plastic, have been used to treat fouling on vessels of up to 113 m long (Mitchell 2007). The wrapping deprives fouling species of light and food while continued respiration and decomposition of organisms within the barrier depletes dissolved oxygen in the water, thus creating an anoxic environment that is eventually lethal to all enclosed organisms.

Polyethylene silage plastic wrap (15 by 300 m, 125 µm thick) is cut to size to suit the vessel type and is deployed by divers in association with a topside support team. The plastic is passed from one side of the vessel to the other, overlapped and secured tightly using PVC tape or ropes to create a dark, anaerobic, watertight environment. Sharp objects on the hull (such as propeller blades) should be wrapped separately or covered with tubing or cloth before encapsulation to prevent tears in the plastic.

Properly deployed, the wrap should contain the pest species and its larvae; care should be taken to ensure that biofouling is not dislodged when the wrap is deployed. The wrap must remain in place for at least seven days to ensure mortality. Wrapping of vessels larger than 25 m in length is labour intensive and may take up to two days to deploy per vessel. In addition, the time needed for effective treatment (seven days) may be too slow when rapid treatment and turnaround of vessels is crucial.

This method of treatment is only suitable in relatively sheltered environments with slow current flow, since strong currents create difficulties in deploying the wrap and increase the chances of tears in the plastic.

Where very large vessels or several vessels need to be treated, the encapsulation technique will generate large amounts of plastic waste. Wrap and equipment used to deploy it must be disposed of in landfill or an approved solid waste treatment facility.

Commercial encapsulation tools are available, which can be applied to a vessel arriving in port, or to a vessel at anchor, alongside a wharf or in a marina berth.

Relevant agencies in each state or territory jurisdiction should be consulted about the suitability of a wrapping and encapsulation method for a vessel or moveable structure.

#### Chemical treatment

Mortality can be accelerated by adding chemical agents to the encapsulated water (Coutts & Forrest 2005). For example, sodium hypochlorite (NaOCl, 12.5% w/v) can be added to the sea water enclosed in the sheath to achieve a concentration of 200 to 400 ppm. The sheath and chemical treatment remain in place for 36 to 48 hours for each vessel. Because this technique may release some chloride ions to the surrounding water, consent is required from relevant state or territory authorities to undertake the treatment.

#### 4.1.3.3 Aquaculture stock and equipment

Treatments used to remove marine pests from ropes, culture lines and equipment include:

- immersion in or spraying with:
  - acetic acid (4%) (Coutts & Forrest 2005; Forrest & Blakemore 2006; LeBlanc et al. 2007)
  - brine or lime solutions (Carver, Chisholm & Mallet 2003)
  - chlorine or sodium hypochlorite (Carver et al. 2003; Coutts & Forrest 2005; Gunthorpe et al. 2001; Rajagopal et al. 2002, 2003)
  - hot (50 °C) or cold (ambient) freshwater (Carver, Chisholm & Mallet 2003; Coutts & Forrest 2005 Gunthorpe et al. 2001; Nel, Coetzee & Vanniekerk 1996)
- air drying (Carver, Chisholm & Mallet 2003; Coutts & Forrest 2005; Gunthorpe et al. 2001)

- high pressure (greater than 2,000 psi) water blasting (Carver, Chisholm & Mallet 2003; Coutts & Forrest 2005).

Table 6 is a summary of treatments shown to cause 100% mortality (LD100) of *Asterias amurensis*. These are largely based on laboratory trials and may need to be adapted to ensure complete mortality on more complex structures such as ropes or nets or for large applications.

Adult *A. amurensis* are moderately tolerant of air-drying (desiccation) over periods of up to 48 hours, with survival rates greater than 40% (Gunthorpe et al. 2001). Although individuals appear stressed and moribund after 24 hours of aerial exposure, they recover quickly when replaced in seawater.

### Table 6 Treatments that achieved total mortality (LD100) of *A. amurensis* in laboratory conditions

| Treatment | Duration of immersion and concentration for 100% mortality |
|---|---|
| Bleach solution (Black and Gold)[a] | 1 hour at 2% concentration[b] |
| Detergent (DECON 90)[c] | Greater than 2 hours at greater than 18 °C[b] |
| Quicklime | 2 weeks[d] |
| Freshwater | Greater than 2 hours at greater than 18 °C |

**a** Active ingredient 3% sodium hypochlorite. **b** Gunthorpe et al. 2001. **c** Active ingredient less than 3% potassium hydroxide. **d** Aquenal 2007; Bax et al. 2002; Goggin 1998.

*A. amurensis* has a relatively narrow tolerance to changes in salinity and is sensitive to a decrease in salinity (Kashenko 2003). Immersion in freshwater for more than two hours causes total mortality of animals in laboratory tests when water temperatures are maintained at 18 °C or higher (Gunthorpe et al. 2001). *A. amurensis* larvae do not develop normally at salinities of less than 8.75% or at temperatures greater than 20 °C.

Laboratory trials have shown that immersion in a 2% bleach solution for an hour or more is an effective way to kill *A. amurensis*. Treatment with bleach is not recommended for decontamination of aquaculture stock, as it also causes high mortality of treated mussels (Gunthorpe et al. 2001).

*A. amurensis* exhibits a variable response to exposure to 2% detergent solution (Gunthorpe et al. 2001). Animals exposed to detergent solutions for two hours or more appear moribund and display tissue necrosis, including loss of arms. All animals treated in this way died within 48 hours of exposure to the detergent (Gunthorpe et al. 2001). Mortality is most rapid when the temperature of the detergent solution is maintained above 18 °C. Detergent treatments are most effective against small *A. amurensis* (less than 90 mm arm length) and are much less effective for very large animals. Solutions of 2% detergent appear to have negligible effects on mussel stock immersed in it for periods of up to four hours.

#### Ropes and equipment

The protocols recommended for treating ropes and aquaculture equipment, such as buoys, floats, nets and traps, are:

1) Remove to land, taking care not to dislodge seastars and other organisms when removing structures from the water.
2) Clean thoroughly by high pressure (greater than 2,000 psi) water blasting.

3) Immerse in fresh water, 2% detergent (DECON 90) or 3% liquid sodium hypochlorite for at least two hours at 18 °C or above.

4) Rinse in seawater and air dry for at least 48 hours.

### Aquaculture stock

Some cultured invertebrate species (particularly shellfish) may have *A. amurensis* feeding on them or sheltering within them and may therefore be potential vectors for its spread. The effectiveness of methods used to decontaminate aquaculture stock will depend on the relative robustness of the pest and cultured stock to the treatment. For example, *A. amurensis* is more susceptible than mussels or oysters to treatments involving submersion in hot and fresh water.

Based on laboratory and field trials, to remove *A. amurensis* from mussel stock Gunthorpe et al. (2001) recommend either:

- declump stock, then immerse in fresh water for at least two hours and air dry overnight

  or

- declump stock, then immerse in 2% detergent (DECON 90) for at least two hours and air dry overnight.

Both protocols resulted in total mortality of *A. amurensis* but caused only minor changes in survival and viability of mussel stock.

These methods are also likely to be cost-effective means of treating other fishing, aquaculture or boating equipment for *A. amurensis*.

Disinfection of bivalves and other aquaculture stock for external hitchhikers is not always effective and must be weighed against potential environmental impacts of any treatment and its effect on stock. Where the treatment cannot be effective, it may be precautionary to either destroy potentially contaminated stock and dispose of it to landfill or harvest and process stock for human consumption.

## 4.2 Tracing an incursion

Tracing is used to discover the method and pattern of the spread of the pests and may include trace-forward and trace-back. It is crucial to defining and modifying the dimensions of the specified areas and requires investigations that determine:

- the length of time the species has been present
- the initial source and location of infestation
- whether the pest has reproduced
- the possible movement of water, vessels, animals, submersible equipment and other potential vectors for the pest
- the existence and location of other potentially infested areas.

If the Local Control Centre is established, it is responsible for managing tracing and surveillance activities within the control area.

Several methods are useful for estimating how long the pest has been present. The demography of the population may be inferred from the size distribution and reproductive state of animals collected during initial investigations.

For example, specimens that have an arm (ray) length of less than 55 mm are likely to be younger than 12 months and therefore non-reproductive (Byrne et al. 1997). *Asterias amurensis* is reproductively mature after one year (see section 1.1.3). Very dense populations can build up rapidly. A population of this species that contains individuals varying widely in size, or that contains two or more distinct size cohorts, may indicate successful local reproduction and multiple recruitment events.

## 4.2.1 Data sources for tracing vectors

### 4.2.1.1 Vessels

Tracing the movements of vessels to and from an incursion is made difficult by lack of a consolidated system for reporting or managing data on vessel movements in Australian waters. Some potentially useful data sources on movements of large, registered commercial vessels are:

- The Lloyd's List Intelligence maintains real-time and archived data on movements of more than 120,000 commercial vessels worldwide. It contains arrival and departure details of all vessels larger than 99 gross tonnes from all major Australian and international ports. The database contains a searchable archive that includes movement histories of boats since December 1997. Searches can be purchased for specific ports, vessels or sequences of vessel movements.
- MarineTraffic provides real-time data on the movements of more than 550,000 vessels. It maintains archived data going back to 2009. Searches can be purchased for specific ports, vessels, areas or periods of time.
- Local port authorities keep records of all vessel movements at their port berths and associated anchorage points.
- The Australian Fisheries Management Authority manages data on the locations of all fishing vessels that have Commonwealth fishing concessions. All Commonwealth fishing concession holders must have installed and be operating an integrated computer vessel monitoring system. The system is also required for some fisheries managed by state and territory fisheries management agencies (such as the Queensland East Coast Trawl Fishery).
- The Bureau of Infrastructure, Transport and Regional Economics maintains statistics on maritime trade, markets, shipping lanes, key trade routes, traded commodities and passenger services throughout Australia.
- The Department of Agriculture and the Australian Border Force maintain data on all vessels arriving in Australian waters from overseas. These data are for proclaimed first ports of entry into Australia.
- The Australian Maritime Safety Authority deals with maritime safety, protection of the marine environment and maritime and aviation search and rescue services. It also coordinates a vessel tracking program, which works as an umbrella for managing related vessel information from the Modernised Australian Ship Tracking and Reporting System (MASTREP) the Great Barrier Reef

and Torres Strait Vessel Traffic Service, the Automatic Identification System, the Long Range Information and Tracking system and the Australian Maritime Identification System.

- The aquaculture industry deals with equipment, stock and boat movements between aquaculture sites.

There are no consolidated data on domestic movements of smaller coastal vessels within Australian waters. Ports and some marina operators keep records of vessels that have used their facilities. Local industry groups (such as fishing, petroleum exploration) may provide points of contact for vessels from individual industry sectors that have visited the infested area. Some data may also be available from sources such as the Australian Volunteer Coast Guard, in the form of logged vessel trip reports.

Some states and territories have developed vessel-tracking systems for a range of vessel types. During the operational period of the *Mytilopsis sallei* incursion in Darwin, the Northern Territory Police and the Australian Government Department of Agriculture, with support and input from the Darwin Port Authority, Australian Border Force, the Northern Territory Fisheries Division Licensing Branch, the Australian Fisheries Management Authority and Coastwatch, developed an access database that contained vessel names and contacts, current location, history of individual vessel movements and the risk status of the vessel.

#### 4.2.1.1 Ocean current modelling

Ocean current modelling may be an effective forward and backward tracing method for estimating the source and sink locations as part of marine pest incursions. There are a number of tools that can assist with modelling of current movements:

- Connie 3 uses archived currents from oceanographic models and particle tracking techniques to estimate connectivity statistics from user-specified source or sink regions. A range of physical and biological behaviours can be specified including vertical migration, horizontal propulsion, swimming, flotation or surface slick formation.
- Regional Ocean Modelling System (ROMS) is an ocean model used for a diverse range of applications. ROMS has pre and post-processing software for data preparation, analysis, plotting and visualisation.

# 5 Controlling, eradicating and treating established populations

The feasibility of controlling an *Asterias amurensis* infestation in Australian waters depends on the nature and location of the incursion and the management strategy adopted. Two control options are available:

- eradication or complete elimination of *A. amurensis* from the infested area (highest level of control measure and cost)

  or

- containment and control by limiting the species to the infested area, preventing further spread and protecting uninfected areas (has ongoing costs and implementation so may have higher cost in the long term).

## 5.1 Eradication

Eradication of *Asterias amurensis* requires complete removal from the infested area. Eradication is unlikely to be successful or feasible if initial investigations determine that the species is widespread, cannot be contained, is difficult to detect, or is present or potentially present in open coastal environments.

Because the planktonic larvae of *A. amurensis* are long-lived and can be spread rapidly over large distances by movement of tidal and coastal currents, eradication may be impossible in open coastal waters where there is high exchange of water. Eradication is most likely to be feasible when:

- the area inhabited by *A. amurensis* is small (less than 1,000 $m^2$)
- the infestation occurs within an area of minimal flushing or exchange of water
- the available habitat occurs in relatively shallow waters (less than 5 m)
- the population is relatively aggregated and has not yet reached reproductive maturity.

These conditions—aggregated population and infestation within an enclosed or semi enclosed area of minimal water exchange—are also the conditions predicted to be best for *A. amurensis* reproductive success and rapid population growth (Bax et al. 2006). Eradication success will, therefore, be highly dependent on early detection of the incursion and response before reproduction has occurred.

## 5.2 Containment and control

If the decision is made not to attempt eradication but to implement containment and control, the Incident Manager will recommend that interim containment measures be implemented to minimise the risk of pest translocation from the infested waterway. This may include movement controls on potential vectors, public awareness campaigns, policies and practices (in consultation with stakeholders) for vessel and equipment sanitation and surveillance, and control of secondary infestations outside the infested waterway.

National control plans (NCPs) have been developed for several marine pests—including *A. amurensis*—that are already established in Australia and are having significant impacts on the marine environment or marine industries. The purpose of the NCP is to reflect an agreed national response to reduce impacts and minimise spread of agreed pests of concern. Each plan includes:

- practical management actions and cost-effective approaches to control or reduce the impact of the marine pest
- recommendations for future research and development, including cost–benefit analysis and planning tools
- links to the National System monitoring strategy
- recommendations for additional public awareness and education strategies
- an implementation strategy.

## 5.3 Guidelines for delimiting surveys

A delimiting survey establishes the boundary of an area considered to be infested by or free from a pest. The survey should be conducted to establish the area considered to be infested by the pest during the emergency response and to decide if eradication is feasible. The State or Local Control Centre will plan a survey strategy with reference to appropriate confidence limits based on:

- the location where the pest was initially detected
- pest biology—survival, reproductive rate, spread, dispersal and influence of environmental factors
- pest habitat—distribution and suitability of potential habitats around restricted areas and control areas
- survey design—should take into account the sensitivity of the methods to detect the pest species and the ease with which a sample may be obtained, as well as operator safety
- sampling methods—should take into account the area of expected occurrence
- a predictive analysis of areas where the pest is likely to occur
- expected prevalence of the pest if unrestricted
- statistical methods to specify the different confidence limits for targeted and general surveillance.

When possible, the survey should be consistent with national standards and contain estimates of confidence based on best available information.

## 5.4 Design of a delimiting survey

The location at which the pest was first detected is a useful starting point for a delimiting survey, but it is important to recognise that it is not necessarily the initial site of the infestation. When designing a delimiting survey, it can be useful to work backward, to try to trace the initial source of the incursion (trace-back) and also to try to predict where the pest has, or could, spread to (trace-forward).

The geographic extent of an incursion will be determined by:

- how long the pest has been present at the site before it was detected
- the frequency and quantity of reproductive output from the population since the initial incursion
- the effects of environmental and human factors on the spread of dispersal stages.

Local knowledge and site inspections as well as satellite imagery, hydrographic charts and online databases such as Seamap Australia can be useful for identifying areas that may contain habitat suitable for the pest. Where they exist, hydrodynamic models (for example, CSIRO's Connie 3) may also be useful for simulating the likely directions of current flow and the possible rate and extent of spread of planktonic larvae from the known area of infestation. Trace-forward techniques should be used to identify locations outside the infested area that may have been exposed to the pests by vectors that have departed the area known to be infested.

Trace back information can also be used to determine the possible extent of an incursion (particularly a primary incursion where a single size class is present). Working backwards from the estimated age of the specimens and the known settlement biology and larval lifecycle of the species, ocean current modelling can predict the source of a spawning event. This source information can then be used to determine where else in the area the prevailing currents could have spread the larvae. The greatest survey effort should be made at the margins of the known infestation. Adaptive sampling designs with sample points located on systematic grids or gradients away from the site of known infestation (Eberhardt & Thomas 1991; Gust & Inglis 2006) are most useful to ensure the greatest possible area is covered, while providing the best chance of detecting established and founding populations.

### 5.4.1 Sampling methods

The type of sampling method chosen should be based specifically on the species being targeted, the habitat being searched and the conditions at the site. *Asterias amurensis* can occur in soft sediment environments, on rocky reefs and on and around hard artificial substrata. In shallow subtidal waters (less than 10 m)—where *A. amurensis* is most abundant and the water is clear—visual surveys by divers, snorkelers or remote or towed video are likely to be the most efficient, as a large area can be searched relatively quickly. Complex artificial structures, such as wharf pilings, pontoons and niche areas of vessels, are most efficiently inspected by divers. ROVs can be used to do this where diving is not an option for safety reasons.

The ability of divers and other forms of visual survey to detect *A. amurensis* depends on sufficient training in identification and search techniques, water clarity at the site and the abundance and degree of aggregation of the population. Where underwater visibility is less than 1 metre, visual surveys may be severely compromised. In these circumstances, visual surveys may be replaced in soft-sediment environments by benthic sled tows, modified scallop dredge, beam trawls or similar techniques that will effectively sample epibenthic assemblages over large areas. Strategic deployment of baited traps may also be used for detection of benthic populations, but tend to be less efficient when natural food resources are abundant (Martin & Proctor 2000).

Artificial structures such as floating pontoons, projecting piles, steel facings, ropes and mooring dolphins that have large densities of mussels and other fouling biota should be considered a high priority during surveying, as they provide concentrated sources of food around which *A. amurensis* may aggregate. Similarly, known shellfish beds or rocky reefs with high densities of shellfish or other invertebrates may be centres of seastar aggregations. Other surfaces which have the potential for colonisation include breakwaters, groynes, rockwalls, wrecks, hulks, moorings, navigational markers, hulls and aquaculture facilities.

*A. amurensis* also inhabits shallow subtidal and intertidal areas, which should be surveyed visually (from shore or sea) during low tide for infestation.

See the Australian marine pest monitoring guidelines, version 2 (NSPMMPI 2010) for additional information that can be adapted for delimiting surveys.

# 6 Methods for treating established populations

Methods used to treat established populations of *Asterias amurensis* will vary in efficacy according to the size and location of the incursion. This chapter summarises treatment options for closed or semi-enclosed coastal environments and for open coastal environments.

## 6.1 Closed or semi-enclosed coastal environments

Eradication is most achievable in closed or semi-enclosed coastal environments (such as locked marinas and coastal lakes) because the pest can be more easily contained and it is possible to maintain conditions necessary to achieve mortality for longer. Various treatment options are possible in these circumstances, including draining, de-oxygenation and/or flushing of the waterway with fresh water, application of chemical biocides, physical removal and ecological control (Aquenal 2007).

If the infestation is confined to relatively small, enclosed or semi-enclosed waterways, it may be possible to treat the entire water body and all marine habitats within it. If this is not possible, the success of management will depend more heavily on the ability of monitoring and delimitation surveys to locate and treat all clusters of the population. Where resources allow, all habitat potentially suitable for *Asterias amurensis* should be treated. Where this is not possible, habitats should be based on suitability for the pest and delimitation survey results.

### 6.1.1 Chemical treatments

Major constraints for chemical treatment of water bodies are the volume of water that needs to be treated (a function of the area, depth and degree of flushing of the waterway), the presence and susceptibility of valued non-target organisms that may also be affected, residual effects of any toxicants on the surrounding environment and human health and safety management when handling large volumes of chemicals. Legal issues can also influence the ability to administer chemicals as a rapid response, due to the large number of chemical products available and different legislative requirements between Australian states and territories (Aquenal 2007). Consideration should be given as to whether a permit for the use of chemicals is required from the relevant state or Northern Territory environment agency or the Australian Pesticides and Veterinary Medicine Authority.

Three approaches have been suggested for chemically treating an established population of invasive *Asterias amurensis*. These are broadcasting chemicals in the water column, injecting chemicals directly into the seastars and using reproductive inhibitors or stimulants. In some situations, salinity manipulation may also prove effective.

#### 6.1.1.1 Broadcast chemicals

The use of broadcast chemicals to eradicate *Asterias amurensis* has been investigated since the beginning of the 1900s. However, its direct use as a means to kill seastars has been deemed socially and environmentally unacceptable because of the large scale required and the severe effects on other marine biota (Australian Government 1999).

### Lime

Lime in either slake or hydrated form has been shown to be one of the most toxic substances to seastars because it is highly alkaline and erodes the carbonate test of seastars. After exposure to lime, or more specifically quicklime (calcium oxide), for 24 to 48 hours, a seastar develops lesions on its test and dies within the following two weeks.

Industrial uses for lime make it a reasonably cheap chemical for broadcast eradication (Aquenal 2007). Direct contact with lime is required for a significant effect to be achieved. This is usually done by either covering a seastar with quicklime or having an even distribution of the lime present on the seafloor for *A. amurensis* to crawl over. The use of quicklime as a deterrent or barrier around commercial production facilities has also been trialled in Korea and Canada (Goggin 1998). Quicklime is deployed in porous bags around a site and the lime slowly diffuses into the water column, either deterring the invasive seastars or killing those which come into contact with it.

In laboratory trials, *A. amurensis* from the Derwent estuary in Tasmania were exposed to quicklime slurry, with little or no significant harm found caused to the seastar. This result suggests that contact with the lime needs to be as long as possible to have an effect on their calcium carbonate test. Contact with lime on human bare skin is toxic and care must be taken when handling this substance (URS Australia 2004).

### Copper sulphate

The only other substance to receive attention for its toxicity on a broad scale against *A. amurensis* was copper sulphate. It was found to kill *A. amurensis* effectively but was not deemed appropriate because of its negative effects on all marine biota (Goggin 1998).

#### 6.1.1.2 Injected toxicants

Applying toxicants through a pole-spear has been effective in controlling the crown of thorns seastar, *Acanthaster planci*. Toxicants proved to be effective at killing *A. planci* include formalin (at different concentrations), copper sulphate, hydrochloric acid and ammonia. Copper sulphate was subsequently recommended as the safest and easiest toxicant to use, and kill rates were usually very close to 100% for nearly every chemical used. The only limitation to the pole-spear is the rate at which chemicals can be applied to seastars. Maximum rates of administering toxins by pole-spear to *A. planci* were approximately 140/hour, when the seastars where packed densely. Rates of approximately 100/hour are more common, with total kills typically ranging from thousands to tens of thousands.

#### 6.1.1.3 Reproductive inhibitors

The use of asterosaponins to inhibit reproduction has been suggested as a species specific method of reducing the species. Its specificity to *Asterias amurensis* would allow broadcast application or addition of the chemical to the diet with little apparent negative effects on native seastars (Goggin 1998). The difficulties of depositing large amounts of endocrine-disrupting compounds into seriously affected areas has been suggested as a limitation to the potential use of these types of chemicals (Goggin 1998).

#### 6.1.1.4 Salinity manipulation

Salinity reduction through redirection of storm water or other freshwater sources into the infested waterway (and/or by removal of sea water), has been used to control the algal pest

*Caulerpa taxifolia* in enclosed waterways in South Australia. Laboratory experiments have shown that *A. amurensis* is susceptible to changes in salinity, as it lacks the protective coverings usually found in bivalves and molluscs (Kashenko 2003).

*Asterias amurensis* appeared stressed and moribund when salinities dropped below 24 ppt, and death occurred at levels less than 18 ppt, in aquaria conditions in Russia (Kashenko 2003). When unfavourable conditions were reached, *A. amurensis* had slower righting times and had weakened attachment to the substrate. In colder temperatures, or when large volumes of freshwater input have occurred into estuaries, migration of *A. amurensis* has been observed into shallower waters. This was originally assumed to be a result of the animals seeking warmer temperatures, but it may also be a result of the animals avoiding lower salinities (Kashenko 2003).

Desiccation and oxidative stress are also effective ways of reducing *A. amurensis* populations but this requires human control of water levels. This type of control option will be most applicable to fouling species in confined areas—such as power plants, raw water systems, reservoirs, locked marinas and impoundments—where the water level is more easily manipulated (Almeida et al. 2005).

### 6.1.2 Physical treatments

Physical removal of an invasive population such as *Asterias amurensis* remains the most socially and environmentally acceptable method employed for near-shore coastal marine environments. Because *A. amurensis* are easily identified and relatively slow moving, the species can be physically removed using techniques including pole spears, mopping, dredging, trawling, dip netting and diver collection (Goggin 1998). The removal technique depends on the type of habitat the pest is located in and the possible effects on the surrounding environment. Strategic deployment of baits or food sources may be useful for aggregating adult *A. amurensis* to allow more efficient collection by hand.

Manual collection has been shown to be effective at reducing populations of *A. amurensis* in some circumstances. In Anderson Inlet, Inverloch, sustained systematic searches and manual removal of *A. amurensis* by divers over 15 months was successful in reducing the population to the limits of detection.

The success of the response was strongly influenced by:

- early detection of the incursion
- the relatively small, aggregated population
- occurrence in relatively clear, shallow waters
- considerable support and commitment from local divers, the Inverloch community, the Victorian Government and relevant government agencies across Australia.

In total, 282 individual *A. amurensis* were removed by hand from an estimated population of 300.

The incursion response team included:

- fishers and boaters who volunteered their time to transport divers to dive locations
- walkers scanning the beaches
- the State Emergency Service, who coordinated and ensured safety on the water

- the Surf Life Saving Club for emergency response preparedness
- the Red Cross, who provided lunches
- a full range of local residents
- various Victorian Government agencies.

However, manual collection is costly, time consuming and less effective when the incursion is large. Diver searches and manual collection were not effective in preventing establishment of *A. amurensis* in Port Phillip Bay after its initial detection (Parry & Cohen 2001).

Similarly, organised collections by dive clubs and the Tasmanian museum in the port of Hobart in 1993 reduced the local abundance of *A. amurensis* but did not significantly alter the viability of the population (Aquenal 2008). More than 6,000 *A. amurensis* were removed from an area 300 m by 20 m, and this was estimated to be around 60% of the expected population in that vicinity. A month later a second, more extensive dive covered a greater area and approximately 24,000 individuals were collected (Goggin 1998). Physical diver removals are not a suitable method for strategic or large-scale control but are more appropriate for tactical removal at local sites.

#### 6.1.2.1 Removable structures

Ropes, mooring lines, buoys, floating pontoons and other structures within the infested area that can be removed from the water should be removed and treated on land. Procedures for treating these structures are described in section 4.1.3.3 and could include:

- disposal to landfill
- air-drying for a minimum of seven days
- high-pressure water blasting
- immersion in chemical or fresh water baths.

#### 6.1.2.2 Hard substrata and structures that cannot be removed from the water

Hard substrata and structures that cannot be removed from the water include intertidal and submerged habitats.

##### Intertidal habitats

Hard intertidal substrata, such as wharf piles, exposed jetties and rocky shorelines may be treated when they are exposed at low tide.

##### Submerged habitats

Trapping has been examined extensively as a means to control *Asterias amurensis* populations. The Whayman-Holdsworth seastar trap has been experimentally trialled to establish the effects of mesh size, trap size and soak times to find the most successful seastar trap. The results indicate that seastar traps caught the most individuals within the first 24 to 48 hours and were more likely to catch larger individuals.

Traps with smaller mesh caught more seastars than traps with larger mesh. More intensive trapping experiments showed that, where the population of *A. amurensis* was low to moderate, traps were not effective at controlling the population, but at higher densities a greater percentage of the population was caught (Goggin 1998). Where areas were infested with seastars, trapping appeared to be the most cost-effective physical method—compared with diver removal—for attempted control of a population (Goggin 1998). In locations with patchy seastar distributions, diver removal was most cost-effective at depths above 12 m.

Wrapping and encapsulation of submerged substrata using impermeable barriers, such as polyethylene plastic, have been used successfully to treat fouling on structures such as wharf piles, jetties, pontoons, vessel moorings, small reefs and aquaculture facilities that cannot be removed from the water (Aquenal 2007).

Black polyethylene plastic bale wrap (1 m wide and 50µm thick) is wrapped over the structures, with an overlap of approximately 0.4 m on each successive layer of wrap, and secured using PVC tape to achieve a water-tight seal. Aquenal (2007) provides procedures for deploying the wrap on different structures and details on the costs involved with this treatment technique. The wrappings can remain in place for extended periods (up to 12 months), providing some protection from reinfection. Should the outside of wrappings become reinfested, their removal provides a second treatment option provided the animals can be retained when the wrap is removed. Areas of the structures that cannot be wrapped effectively may be treated by commercial divers using an underwater flame torch.

Encapsulation techniques are most suited to treating small-sized to medium-sized incursions (less than 10,000 m$^2$) in relatively sheltered waters. The procedure is very labour intensive and there are hazards associated with its deployment by divers. The wrap is susceptible to puncture and tear by shipping, strong water currents and sharp oysters or tubeworms, which reduces its effectiveness. The technique is non-selective and all organisms contained within the wrapping will be killed.

Encapsulation or other containment techniques may also be used in combination with chemical treatment to achieve faster kill rates. Chemicals are injected into the covered area to maintain elevated concentrations of the biocide in close proximity to the fouled surface (Aquenal 2007).

#### 6.1.2.3 Soft sediment habitats

The use of mops to collect seastars has been common in the aquaculture industry since the early 1930s, especially around oyster beds (Aquenal 2008). Historically, a mop consisted of 12 to 16 large yarn brushes, 1.5 m long, connected to a large iron bar. The iron bar was dragged along behind a vessel to catch seastars and bring them to the surface, where they were killed by submerging them in hot water (Aquenal 2008). Modern mopping is similar, with a metal frame covered in yarn used to catch seastars. In an alternative form of mopping, in Long Island, Connecticut, a rotor cable picks up seastars by their spines to bring them to the surface for immersion in boiling water (McEnnulty et al. 2001). Adaptations of the mop have been used in other countries with varying success (McEnnulty et al. 2001). Mopping was not recommended for the population in the Derwent estuary, Tasmania, or in Port Phillip Bay, Victoria, because of possible resuspension of toxic dinoflagellates and heavy metals from the sediment (McEnnulty et al. 2001).

In soft muddy sediments, *Asterias amurensis* may be removed by trawling or dredging. The type of dredge used determines the effectiveness of the technique. Dredges normally used in bivalve fisheries (such as scallop dredges) are most efficient on soft, flat, muddy sediments but are highly size-selective. The size of mesh used on the dredge determines the size range of animals captured.

In shipping ports and marinas, it may be possible to use the large, cutter-suction dredges used for capital work to remove the upper layers of sediment (including any seastars) from throughout the infested area. Screening and disposal of the sediment removed from the infested area must ensure that no viable fragments are returned to the water. To be effective, the dredging program must be accompanied by monitoring to ensure that it treats as much of the infested area as possible.

Substrate dredging and suction dredging were not recommended for use in Tasmania or Port Phillip Bay, Victoria, due to the resuspension of toxic materials and the significantly large bycatch associated with these methods. Dredging in Australian waters is generally prohibited unless consent is sought.

An alternative to sediment removal is smothering by deposition of uncontaminated dredge spoil (Aquenal 2007). Technical advice should be sought on the source, type and quantity of sediment needed to ensure mortality of seastars in treated areas. The efficacy of dredge spoil as a treatment option is also influenced by the mobile nature of the species and conditions at the site. It is most likely to be a viable option in sheltered areas where the seabed topography is relatively simple, to maximise persistence of the capping. Deposited sediment will be dispersed rapidly in high energy, or highly complex habitats (such as rocky reef). The availability of a sufficient volume of uncontaminated dredge spoil also needs to be considered, and any permits or government requirements (Aquenal 2007).

## 6.2 Open coastal environments

Limited emergency eradication response options are available to deal with marine pest incursions occurring in open coastal environments, particularly on high-energy coastlines or in deep water (more than 10 m). Many treatment options described in section 6.1 may be applied to small-scale incursions in these environments, but the main difficulties occur in containing the larvae and maintaining treatment conditions in a lethal state for sufficient time. The latter requires deployment of structures or application technologies that allow delivery of chemicals or encapsulation techniques over large areas and which are robust to water movement.

Successful eradication of small incursions may be possible using simple methods (such as manual removal, smothering, small-scale containment and chemical treatment) if the incursion is detected early or where site-specific conditions allow removal or containment of the *Asterias amurensis* and treatment method.

## 6.3 Monitoring and ongoing surveillance

Monitoring and surveillance are used to detect new populations or clusters of *Asterias amurensis* and to inform the eradication and control programs. Active surveillance for the presence of *A. amurensis* in restricted and control areas should continue until the incursion is declared eradicated or until the emergency response is stood down. If a zoning program is implemented, it will be necessary to implement targeted active surveillance for the species outside the restricted and control areas to support the declaration of zones free from *A. amurensis*. The Australian Monitoring Design Package (Version 1c), including the Australian marine pest monitoring manual and guidelines, can be used to help determine appropriate sampling intensity for ongoing surveillance.

Several methods may be appropriate for surveillance:

- systematic, targeted searches by divers or ROVs of suitable or treated sub-tidal habitat within the restricted area or at sites at risk of infection
- systematic, targeted searches by shoreline observers of suitable or treated intertidal habitat within the restricted area or at sites at risk of infection
- targeted searches and inspection of vessels and other vectors departing, or which have left, the control area
- regular screening of plankton tow samples for *A. amurensis* larvae using the real-time PCR probe described by Bax et al. (2006)
- regular monitoring of spat-collection devices within the restricted area or at sites at risk of infection
- regular sample collection and analysis using molecular detections methods such as polymerase chain reaction (PCR).

The Victorian Marine and Freshwater Resources Institute trialled the use of scallop spat collectors for monitoring settlement of *A. amurensis* in Port Phillip Bay (Parry, Werner & Heislers 2003). Sutton and Hewitt (2004) recently evaluated their use for monitoring *A. amurensis* by examining data on regular catches of juvenile *A. amurensis* in spat bags deployed in areas of Tasmania that did not contain sizeable adult populations. They concluded that spat bags were a relatively sensitive means of detecting settlement of *A. amurensis*, even where benthic populations occurred at relatively small densities. A protocol for deployment of spat bags is given in Appendix C.

Bax et al. (2006) described the development and trial of a real-time PCR gene probe that is highly sensitive and specific to *A. amurensis* and can be used to quantify concentrations of larvae in water samples. A protocol for collecting plankton samples for analysis using the gene probe is described in Appendix D.

PCR tests should be validated to quantify the sensitivity and specificity of assays. Your testing laboratory should be consulted as part of planning molecular surveillance activities.

# Appendix A: Guidelines for using the Biosecurity Act during an emergency response to a marine pest of national significance

The following is an interim process for using the Biosecurity Act for action on vessels to treat contaminations by a marine pest of national significance. The Biosecurity Act may be used in certain circumstances, including where a biosecurity officer suspects on reasonable grounds, that the level of biosecurity risk associated with the vessel is unacceptable. Under these circumstances, a biosecurity officer may, in relation to a vessel that is under biosecurity control direct:

- the person in charge or operator of a vessel not to move, interfere with or deal with the vessel
- the person in charge or operator of a vessel to move the vessel to a specified place, including a place outside of Australian territory
- a vessel to undergo treatment action deemed necessary by the biosecurity officer
- that other biosecurity measures which may be prescribed by regulations be undertaken.

In addition, biosecurity officers may exercise certain powers, such as taking samples of ballast water from vessels, for the purpose of monitoring compliance with provisions for the management of ballast water at a port or offshore terminal within the outer limits of the EEZ of Australia. Where the Director of Biosecurity (or delegate) is satisfied that a sample of the vessel's ballast water indicates that the vessel poses an unacceptable level of biosecurity risk, then the Director may give a direction to the vessel not to discharge ballast water until conditions specified in the direction are met.

The conditions of using the Biosecurity Act are:

- The Australian Government Department of Agriculture is to be contacted before taking the proposed action to determine the appropriate provisions of the Biosecurity Act that apply.
- Directions to take action under the Biosecurity Act are to be given by a biosecurity officer. Officers of a state or territory government must be authorised as biosecurity officers under the Biosecurity Act to be able to give directions under the Act.
- Actions under the Biosecurity Act should only be taken for vessels currently identified as at risk of spreading a marine pest of national significance.

Responsibility for directing and approving action under the Biosecurity Act rests with the biosecurity officer, but the actual vessel control and treatment actions are handled by the Local or State Control Centre. As a matter of policy, the following information should be provided to the Australian Government Department of Agriculture to help determine appropriate application of the Biosecurity Act:

- the proposed course of action
- the location of proposed action
- details to identify the vessel involved in the proposed action
- contact details of local management agencies that will be managing the vessel control and treatment.

# Appendix B: State and territory legislative powers of intervention and enforcement

The Intergovernmental Agreement on Biosecurity (IGAB), is an agreement between the Australian, state and territory governments. It came into effect in January 2019 and replaced the previous IGAB which started in 2012. The agreement was developed to improve the national biosecurity system by identifying the roles and responsibilities of governments and outlining the priority areas for collaboration to minimise the impact of pests and disease on Australia's economy, environment and community. The National Environmental Biosecurity Response Agreement was the first deliverable of the IGAB and sets out emergency response arrangements, including cost-sharing arrangements, for responding to biosecurity incidents primarily affecting the environment and/or social amenity and when the response is for the public good. In combination with the IGAB, Commonwealth, state and territory governments are responsible under their principle fisheries management legislation to respond consistently and cost-effectively to a marine pest incursion.

### Table B1 Commonwealth, state and territory legislation covering emergency response arrangements

| Jurisdiction | Agency | Principle fisheries management acts covering emergency response arrangements | Marine pest contact website |
|---|---|---|---|
| Commonwealth | Department of Agriculture and Water Resources Department of Agriculture | *Fisheries Management Act 1991*<br>*Biosecurity Act 2015* | agriculture.gov.au/fisheries |
| New South Wales | NSW Department of Primary Industries | *Fisheries Management Biosecurity Act 1995*<br>Fisheries Management (General)Biosecurity Regulation 2017<br>Fisheries Management (Aquaculture) Regulation 2012<br>*Ports and Maritime Administration Act 1995*<br>*Marine Parks Regulation 1997*<br>*Marine Safety Act 1998* | dpi.nsw.gov.au/fishing/pests-diseases |
| Victoria | Victorian Fisheries Authority; Department of Jobs, Precincts and Regions (Agriculture Victoria) | *Fisheries Act 1995* (protection of fisheries)<br>*Environment Protection Act 1970* (management of ballast water)<br>Marine and Coastal Act 2018 | https://vfa.vic.gov.au/operational-policy/pests-and-diseases/noxious-aquatic-species-in-victoria/aquatic-pests |

| | | | |
|---|---|---|---|
| | | *Marine Safety Act 2010* (power of Harbour Masters to direct vessels and duty of harbour masters to minimise adverse impacts on environment)<br>*Port Management Act 1995* (where no harbour master appointed, powers to direct vessels and act to minimise adverse effects on the environment) | |
| Queensland | Department of Agriculture and Fisheries | *Fisheries Act 1994*<br>*Biosecurity Act 2014* | daff.qld.gov.au/fisheries/<br>www.qld.gov.au/environment/coasts-waterways/marine-pests |
| South Australia | Primary Industries and Regions SA | *Fisheries Management Act 2007* | pir.sa.gov.au/biosecurity/aquatics |
| Western Australia | Department of Fisheries | *Fish Resources Management Act 1994* (under review) | fish.wa.gov.au/Sustainability-and-Environment/Aquatic-Biosecurity/Pages/default.aspx |
| Tasmania | Department of Primary Industries, Parks, Water and Environment | *Living Marine Resources Management Act 1995* | dpipwe.tas.gov.au/biosecurity-tasmania/aquatic-pests-and-diseases |
| Northern Territory | NT Department of Primary Industry and Resources | *Fisheries Act 1988* | nt.gov.au/marine/for-all-harbour-and-boat-users/biosecurity/aquatic-pests-marine-and-freshwater |

# Appendix C: Using spat bags to detect *A. amurensis* recruitment

The material in this appendix is sourced from Sutton and Hewitt 2004.

Spat bags provide a substrate for *Asterias amurensis* larvae to settle onto when they have completed their planktonic phase. They should be deployed at times of the year when *A. amurensis* larvae are expected to be present in the water. In Port Phillip Bay, Victoria, larvae are present in the water between May and early November. In the cooler waters of the Derwent River (Tasmania) they are likely to be present for longer—between May and January.

## Spat bags

Spat bags used for scallop settlement can be purchased commercially. They are made of knitted polyethylene mesh netting. Mesh size can vary from 0.75 mm to 3 mm or larger; 1.5 to 3 mm mesh is most commonly used for scallop spat. The bags are typically 40 cm by 80 cm and have an open top that is held shut with a drawstring. Spat settle onto pieces of polyethylene netting (Netron™) placed inside the spat bag. These usually have a larger mesh (12–15 mm) than the spat bag and are strips of approximately 40 by 100 cm.

Two pieces of the mesh should be put in each spat bag. The mesh is scrunched up so it creates a three-dimensional structure through which water can flow easily. The spat bag is then closed using the drawstring.

## Deployment

Sutton and Hewitt (2004) recommend deploying the bags from a fixed structure such as a wharf or jetty, but they can also be deployed using subsurface moorings or weights where these structures are not present. The spat bags are deployed on a weighted and buoyed rope. The bags are attached to the rope using cable ties, about 1 m up from the weight that will anchor it to the seafloor. The top of the rope should be secured to a marked buoy or fixed structure.

## Retrieval

Bags should be retrieved no sooner than four months after deployment. The longer the bags are left out, the larger the *A. amurensis* will be, making them easier to identify, but this also increases the chance of mortality from predation or starvation.

Lift the spat bags out of the water. Jiggle each bag up and down a few times to remove as much silt and weed as possible. This will make sorting the samples easier. Snip the cable ties with wire cutters, undo the drawstring and place the contents of the bag in a 2 mm sieve. Rinse the mesh a few times with seawater and place the contents of the sieve into a labelled ziplock bag or plastic container. Keep it chilled until it can be frozen or sorted in the laboratory.

Each sample should be labelled with:

- details of the location in which it was collected (latitude and longitude)
- date of deployment and retrieval
- sample identifier (such as number in sequence of samples)
- date collected
- name of collector.

## Processing

Place sample contents into a sorting tray and examine the mesh square by square, using forceps. *A. amurensis* retrieved from the bags may range in size from 2 to 30 mm, depending on when they settled and the food available in the bags, but they should be visible to the naked eye. A magnifying glass or binocular microscope may be useful for sorting samples with small or few specimens.

# Appendix D: Using plankton samples to detect *A. amurensis* larvae

Guidelines for collecting and preserving plankton samples to detect and quantify *Asterias amurensis* larvae. The material in this appendix is sourced from Bax et al. 2006.

Plankton samples should be collected using bongo nets or drop nets of 70 cm diameter and mesh of 100µm.

Samples collected using bongo nets are obtained by towing the net behind a vessel obliquely from the seafloor (if shallower than 10 m depth) to the water surface. Tow length may vary between two and 10 minutes, depending on the biomass obtained in the samples.

A mechanical flow meter should be fitted to the net frame and used to estimate the volume of water filtered for each tow. Drop nets are deployed while the vessel is at rest and are allowed to sink from the water surface to about 1 m from the bottom, at a sinking rate of approximately 1 m/minute before they are retrieved.

A choke collar on the net prevents re-sampling as the net is retrieved.

After each deployment, the nets should be rinsed using a bilge pump and the sample from each net should be washed in separate, small net sieves with 100µm mesh, to remove as much seawater as possible.

Samples are then rinsed into sample jars with SET buffered reagent-grade ethanol, ensuring the ratio of biomass to SET buffered ethanol is no more than 1 to 3.

Each sample should be labelled with:

- details of the location in which it was collected (latitude and longitude)
- method used to collect the sample (plankton tow or drop net)
- sample identifier (such as number in sequence of samples)
- date collected
- name of collector.

Additional information collected with the sample (such as environmental variables, tow speed and duration, depth of collection) should be recorded separately and include details of the date of collection, sample identifier, method used and location details.

# Glossary

| Term | Definition |
| --- | --- |
| CCIMPE | Consultative Committee on Introduced Marine Pest Emergencies |
| DSE | Department of Environment and Primary industries (Victoria) |
| EMPPlan | Emergency Marine Pest Plan |
| IGAB | Intergovernmental Agreement on Biosecurity |
| IMO | International Maritime Organization |
| NBIRP | National biosecurity incident response plan |
| NEBRA | National Environmental Biosecurity Response Agreement |
| NIMPIS | National Introduced Marine Pest Information System |
| RRM | Rapid response manuals |

# References

Almeida, E, Bainy, A, Dafre, A, Gomes, O, Medeiros, M & Di Mascio, P 2005, 'Oxidative stress in digestive gland and gill of the brown mussel (*Perna perna*) exposed to air and re-submersed', *Journal of Experimental Marine Biology and Ecology*, vol. 318, no. 1, pp. 21–30.

Aquenal 2007, *Pre-developing technology for marine pest emergency eradication response: Review of current technology*, a draft report prepared for the Australian Department of Agriculture, Fisheries and Forestry Project, Canberra.

Aquenal 2008, National control plan for the Northern Pacific seastar 'Asterias amurensis', report prepared for the Australian Department of Agriculture, Canberra.

Bax, N, Dunstan, P, Gunaskera, R, Patil, J & Sutton, C 2006, Evaluation of national control plan management options for the north Pacific seastar 'Asterias amurensis', Project 46629 final report, May 2005, Natural Heritage Trust, Australian Government, Canberra.

Bax, N, Hayes, KR, Marshall, A, Parry, D & Thresher, R 2002, 'Man-made marinas as sheltered islands for alien marine organisms: Establishment and eradication of an alien invasive marine species', in CR Veitch & MN Clout (eds), *Turning the tide: the eradication of invasive species*, pp. 26–39, paper presented at the International Conference on Eradication of Island Invasives Auckland, New Zealand 19-23 February 2001

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.

Byrne, M, Morrice, MG, Wolf, B 1997, 'Introduction of the northern Pacific asteroid *Asterias amurensis* to Tasmania: reproduction and current distribution', *Marine Biology*, vol. 127, pp. 673–85.

Carver, CE, Chisholm, A & Mallet, AL 2003, 'Strategies to mitigate the impact of *Ciona intestinalis (L)* biofouling on shellfish production', *Journal of Shellfish Research*, vol. 22, no. 3, pp. 621–31.

Coutts, A & Forrest, B 2005, *Evaluation of eradication tools for the clubbed tunicate, 'Styela clava'*, Cawthron report no. 1110, prepared for Biosecurity New Zealand, Cawthron Institute, Nelson, New Zealand.

Department of AgricultureDepartment of Agriculture2017, Australian ballast water management requirements version 7, Department of Agriculture, Canberra.

Deagle, BE, Bax, N, Hewitt, L & 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. 709–19.

Dommisse, M & Hough, D 2004, Controlling the northern Pacific seastar ('Asterias amurensis') in Australia, final report for the Australian Government Department of the Environment and Heritage, State of Victoria, Melbourne.

DSE 2001, 'Synthesis of workshop on management focussed *Asterias* research', 4 June, Department of Sustainability and Environment, Victoria.

Eberhardt, LL & Thomas, JM 1991, 'Designing environmental field studies', *Ecological Monographs*, vol. 61, no. 1, pp. 53–73.

Ferguson, R 2000, The effectiveness of Australia's response to the black striped mussel incursion in Darwin, Australia, a report of the marine pest incursion management workshop 27–28 August 1999, Department of Environment and Energy, Canberra.

Floerl, O 2004, Protocol to quantify the level of fouling (LoF) on vessel hulls using an ordinal rank scale, unpublished report for New Zealand Ministry of Fisheries project ZBS2004-03, Wellington, New Zealand.

Forrest, B & Blakemore, KA 2006, 'Evaluation of treatments to reduce the spread of a marine plant pest with aquaculture transfers', *Aquaculture*, vol. 257, pp. 333–45.

Goggin, CL 1998, Proceedings of a meeting on the biology and management of the introduced seastar 'Asterias amurensis' in Australian waters, CSIRO technical report no. 15, Centre for Research on Introduced Marine Pests, Hobart.

Gunthorpe, L, Mercer, K, Rees, C & Theodoropoulos, T 2001, *Best practices for the sterilisation of aquaculture farming equipment: a case study for mussel ropes*, Marine and Freshwater Resources Institute Report, no. 41, Marine and Freshwater Resources Institute, Queenscliff.

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. 339–53.

Hayes, K, McEnnulty, F, Gunaskera, RM, Patil, JG, Green, M, Lawrence, E, Barry, S, Sliwa, C, Migus, S & Sutton, C 2007, Ballast water decision support system service level agreement Part II, final report for the Department of Agriculture, CSIRO Division of Marine and Atmospheric Research, Hobart.

Hayes, K, Sliwa, C, Migus, S, McEnnulty, F & Dunstan, P 2005, National priority pests—part II: ranking of Australian marine pests, report to the Department of Environment and Energy, CSIRO Marine Research, Melbourne, p. 102.

Holliday, I 2005, *Debriefing report: The emergency response to the northern Pacific seastar outbreak at Inverloch 2004/2005*, prepared by Marine Biodiversity and Natural Resources, Victorian, Department of Sustainability and Environment, Melbourne.

Hutson, KS, Jess Ross, DJ, Day, RW & Ahern, JJ 2005, 'Australian scallops do not recognise the introduced predatory seastar *Asterias amurensis*', *Marine Ecology Progress Series*, no. 298, pp. 305–09.

Kashenko, SD 2003, 'The reaction of the starfish *Asterias amurensis* and *Patiria pectinifera* (*Asteroidea*) from Vostok Bay (Sea of Japan) to a salinity decrease', *Russian Journal of Marine Biology*, vol. 29, no. 2, pp. 110–14.

Kim, YS 1968, 'Histological observations of the annual change in the gonad of the starfish *Asterias amurensis* Luken', *Bulletin of the Faculty of Fisheries*, Hokkaiko University, vol. 19, pp. 97–108.

LeBlanc, N, Davidson, J, Tremblay, R, McNiven, M & Landry, T 2007, 'The effect of anti-fouling treatments for the clubbed tunicate on the blue mussel, *Mytilus edulis*', *Aquaculture*, vol. 264, pp. 205–13.

Lewis, JA & Dimas, J 2007, Treatment of biofouling in internal seawater systems—phase 2, Maritime Platforms Division, Defence Science and Technology Organisation, Fishermans Bend, Victoria.

Ling, SD & Johnson, CR 2009, Native spider crab causes high incidence of sub-lethal injury to the introduced seastar 'Asterias amurensis', proceedings of the 13th International Echinoderm Conference, Hobart, 5–8 January 2009, pp. 195–201.

Martin, R & Proctor, C 2000, Tasmanian marine farm pest monitoring project, final report for National Heritage Trust/Coast and Clean Seas Project IMP16/97, CSIRO, Division of Marine Research, Centre for Research on Introduced Marine Pests, Hobart.

McEnnulty, FR, Bax, N, 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, technical report no. 23, CSIRO Marine Research, Hobart.

McManus, T & Proctor, C 2001, 'Bad news from Henderson Lagoon', *Invertebrata*, no. 20, Queen Victoria Museum and Art Gallery, Launceston, Tasmania.

MCFFA 1999, National policy for the translocation of live aquatic organisms: issues, principles and guidelines for implementation, Ministerial Council on Forestry, Fisheries and Aquaculture, Canberra.

Mitchell, GK 2007, *Hull encapsulation as an incursion response tool for marine fouling organisms: a method trial on a large vessel*, Golder Kingett Mitchell Ltd, Auckland, New Zealand, p. 37.

Nel, R, Coetzee, PS & Vanniekerk, G 1996, 'The evaluation of two treatments to reduce mud worm (*Polydora hoplura Claparède*) infestation in commercially reared oysters (*Crassostrea gigas Thundberg*)', *Aquaculture*, vol. 141, pp. 31–9.

NIMPIS 2002, 'Asterias amurensis' (northern Pacific seastar) species summary, National Introduced Marine Pest Information System.

NSPMMPI 2010, Australian marine pest monitoring manual, version 2, National System for the Prevention and Management of Marine Pest Incursions, Department of Agriculture, Canberra.

Parry, G, 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.

Parry, GD & Cohen, BF 2001, *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 report no. 33, Queenscliff, Victoria.

Proctor, C & McManus, T 2001, '*Asterias amurensis* and Henderson's Lagoon', *Invertebrata*, no. 21, Queen Victoria Museum and Art Gallery, Launceston, Tasmania.

Rajagopal, S, van der Gaag, M, Van der Velde, G & Jenner, HA 2002, 'Control of brackish water fouling mussel, *Mytilopsis leucophaeta* (Conrad), with sodium', *Archives of Environmental Contamination and Toxicology*, vol. 43, no. 3, pp. 296–300.

Rajagopal, S, Venugopalan, V, Van der Velde & G, Jenner, HA 2003, 'Comparative chlorine and temperature tolerance of the oyster *Crassostrea madrasensis*: implications for cooling system fouling', *Biofouling*, vol. 19, pp. 115–24.

Regan, TJ, McCarthy, MA, Baxter, PWJ, Dane Panetta, F & Possingham, HP 2006, 'Optimal eradication: when to stop looking for an invasive plant', *Ecology Letters*, vol. 9, no. 7, pp. 759–66.

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.

Sutton, CA & Bruce, BD 1996, Temperature and salinity tolerances of the larvae of the northern Pacific seastar 'Asterias amurensis', CSIRO technical report no. 6, Centre for Research on Introduced Marine Pests, CSIRO Division of Fisheries, Hobart.

Sutton, CA & Green, MA 1999, *Staging guide for the larvae of the northern Pacific seastar 'Asterias amurensis'*, CSIRO technical report no. 19, Centre for Research on Introduced Marine Pests, CSIRO Marine Research, Hobart.

Sutton, CA & Hewitt, CL 2004, *Detection kits for community-based monitoring of marine pests*, final report for National Heritage Trust Coasts and Clean Seas Program project 21247, CSIRO Marine Research, Hobart.

URS Australia 2004, Best practice for the management of introduced marine pests: a review (pdf 1.92 mb), Global Invasive Species Programme.

Woods, C, Floerl, O, Fitridge, I, Johnston, O, Robinson, K, Rupp, D, Davey, N, Rush, N & Smith, M 2007, *Efficacy of hull cleaning operations in containing biological material: II. Seasonal variability*, MAF Biosecurity New Zealand Technical Paper Series 08/11, prepared for BNZ Pre-clearance Directorate by National Institute of Water and Atmospheric Research Ltd.