



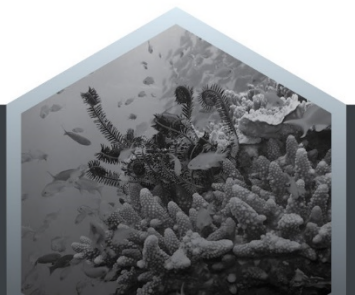
Australian Government

MARINE
PESTS

Rapid response manual generic

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Nationally agreed guidance material endorsed by the Marine Pest Sectoral Committee



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Disclaimer

These manuals are part of a series of documents providing detailed information and guidance for emergency response to key marine pest species or groups of pest species.

The manuals are made available on the understanding that the Commonwealth of Australia is not thereby engaged in rendering professional advice. The Commonwealth does not warrant the accuracy, currency or completeness of the guidelines, or their relevance for any particular purpose. In particular, it should be noted that legislation, regulations and by-laws may vary between different jurisdictions and ports in Australia. Consequently, the guidelines do not purport to state what is necessary or sufficient to comply with laws applying in any place.

Before relying on the manuals in any important matter, users should obtain appropriate professional advice to evaluate their accuracy, currency, completeness and relevance for their purposes.

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 response¹ 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 (EMPPPlan) 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 EMPPPlan 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 incursion, suspected or confirmed, of an introduced marine pest that is considered a pest of national concern, but for which a species-specific rapid response manual does not yet exist.

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 EMPPPlan rapid response manuals and related guidance materials). Changes to the manual include new information on molecular surveillance methods, changes based on experience gained by the *P. viridis* response near Weipa in 2017-18 and updates to biosecurity legislation on policy (*Biosecurity Act 2015*). 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

To recommend changes to this document, forward your suggestions to:

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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](#) (RRMs) have been prepared for several marine pests that the Marine Pest Sectoral Committee (MPSC) has identified as being of national concern. This manual was written to help manage emergency responses to marine pests of national concern for which a species-specific RRM has not yet been developed.

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.

Assemble this information rapidly from reliable sources. Give preference to 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. Use reputable secondary sources of information, such as internet databases and 'grey' literature to supplement this advice or to prepare summary information and plans for expert review.

This document provides guidance on:

- approaches to determining the nature and invasion history of a potential pest
- vectors that facilitate spread of pest species
- generic guidance on information needed to determine an appropriate response to the incursion
- 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 Identify the pest

Determining the identity of a suspected marine pest is the first step in initiating a marine pest emergency response (Chapter 4). This normally requires specimens recovered from a suspected incursion to be examined by a recognised taxonomic expert or diagnostic facility. Relevant research and curatorial staff within state and territory museums and research institutions should also be consulted, because they are connected to national and international networks of taxonomic and systematic expertise and may provide advice on the most appropriate experts to identify the specimen.

For many organisms, identification is only possible if key diagnostic features are preserved appropriately when the specimen is collected. Guidance on appropriate techniques for collecting and preserving specimens from different marine taxa is presented in [Appendix A](#).

1.2 Determine nature of the pest

Questions when trying to determine the nature of the pest include:

- Is the species a marine pest of national concern?
- Does it have a demonstrable history of invasion?
- What are its life history, ecology and environmental tolerances?
- What is its potential impact?

1.2.1 Is the species a marine pest of national concern?

A marine pest emergency may be declared when a marine pest species causes a biosecurity incident meeting the national significance criteria outlined in the [National Environmental Biosecurity Response Agreement](#) (NEBRA). The Consultative Committee on Introduced Marine Pest Emergencies (CCIMPE) may determine that a marine pest species poses a significant potential or actual threat to any part of Australia's marine environment or industry ([chapter 4](#)).

The [Australian Priority Marine Pest List \(APMPL\)](#) includes species that have been agreed as being of national concern. Nine species are listed, with six of these being exotic. These species meet the criteria of the NEBRA as being species of national significance and would be potentially eligible for cost sharing of a biosecurity response. A [priority list of exotic environmental pests and diseases](#) has also been developed and includes exotic marine pest species of national significance.

Table 1 Australian Priority Marine Pest List

Species	Established/Exotic	List membership
<i>Asterias amurensis</i>	Established	APMPL
<i>Carcinus maenas</i>	Established	APMPL
<i>Charybdis japonica</i>	Exotic	PLEEPD
<i>Eriocheir sinensis</i>	Exotic	PLEEPD
<i>Mytilopsis sallei</i>	Exotic	APMPL/PLEEPD
<i>Perna canaliculus</i>	Exotic	APMPL
<i>Perna perna</i>	Exotic	APMPL
<i>Perna viridis</i>	Exotic	APMPL/PLEEPD
<i>Rhithropanopeus harrisi</i>	Exotic	APMPL
<i>Undaria pinnatifida</i>	Established	APMPL

CCIMPE may also consider an emergency response to marine pests not on any lists if they meet at least one of the NEBRA national significance criteria, which relate to:

- the environment
- people, including human infrastructure and social amenity
- business activity.

These species will be considered on a case-by-case basis, using as much information as possible to determine whether the species warrants activation of an emergency response and development of a National Biosecurity Incident Response Plan (NBIRP).

1.2.2 Does the species have a demonstrable history of invasion?

To demonstrate a history of invasion, the investigation must be able to show that:

- the species has previously established self-sustaining populations outside its native range as a result of intentional or accidental transport by a human-mediated vector (or vectors)
- and
- the non-native populations have affected the economy, environment, human health or amenity of the region in which they established.

1.2.3 What are the life history, ecology and environmental tolerances of the species?

A variety of information on the life history, habits, ecology and environmental tolerances of the species is needed to understand the way pest populations develop, spread and cause impacts. Understanding these dynamics is also important for developing a response plan. The type of information needed to determine the nature of the pest is summarised in Table .

Table 2 Life history of suspect marine pest

Feature	Further explanation
Maximum size of adult stage	na
Maximum age of adult stage	na
Maximum duration of juvenile stage	na
Time to sexual maturity	na
Size at sexual maturity	na
Type of reproduction	Sexual/asexual
Mating strategy	Internal/external fertilisation
Dispersal stage	Gametes/juveniles/adults
Potential dispersal distance (single generation)	na
Feeding mode	Autotrophic/herbivore/planktivore/predator/deposit feeder
Depth range	na
Preferred habitat	na
Distribution within population	Gregarious/scattered/solitary
Environmental tolerances	Salinity, temperature, pH, toxicant

na Self-explanatory.

Standardised life history categories may help estimate the potential costs and feasibility for marine pest eradication (Table), in combination with information on location and extent of an infestation (Table , Table , Table and Table).

Table 3 Standardised life history variables

Variable	Levels
Size of organism	Small: less than 5 cm Large: greater than 5 cm
Appearance (camouflage or other)	Cryptic Obvious
Habit	Solitary Grouped
Preferred habitat	Pelagic Benthic, hard substrate Benthic, soft substrate Benthic, hard and soft substrate
Larval duration/incubation period	Short: hours to days Medium: days to weeks Long: weeks to months
Time to maturity from settlement to hatching	Short: less than 2 months Medium: 2 to 12 months Long: greater than 1 year
Propagules per reproductive event	Low: less than 10,000 Moderate: 10,000 to 1,000,000 High: greater than 1,000,000
Sexual reproductive cycles per year	Annual Biannual More frequent/continuous

Source: Crombie et al. 2007

Multiple types of information on the life history can be useful in evaluating the likely success of an eradication attempt and in designing an appropriate response to an incursion.

1.2.3.1 Reproduction and growth

Reproductive method

Marine organisms exhibit a wide variety of mating systems and modes of reproduction. Many are capable of reproducing both sexually and asexually. Different modes of reproduction can lead to more rapid population growth or greater dispersal potential.

Types of asexual reproduction can include:

- fragmentation: a new organism grows from a fragment of the parent (such as some polychaete worms, starfish, sponges, algae)
- budding: small buds are produced from the body tissues of the parent, which grow to be miniature adults and break away from the adult when they are mature (such as some hydrozoa, bryozoans, ascidians)
- vegetative growth: new individuals are formed through growth of specialised leaves, bulbs, rhizomes or stolons (such as seagrass, and stoloniferous algae; for example *Caulerpa taxifolia*)

- spore formation: some algae produce spores by mitosis that are capable of regenerating into an adult plant (such as *Polysiphonia* species)
- parthenogenesis: an unfertilised egg develops into a new individual (such as some small crustaceans; for example cladocerans and ostracods).

Marine species that reproduce sexually also display a range of different mating strategies. In some groups, the sexes are separate and fertilisation occurs internally through copulation (internal fertilisation) of separate male and female individuals (such as most decapod crustaceans and cephalopods). This requires aggregation and direct physical contact between mating individuals. Other groups release fertile gametes into the water and fertilisation occurs outside the female body (such as most fish species, corals), or the female retains the eggs but males shed sperm and fertilisation can occur within the body cavity (such as some species of polychaetes).

In many marine invertebrates, algae and some fish, individuals are capable of producing both male and female sexual organs (hermaphroditism). This can occur either simultaneously or sequentially. Some hermaphroditic species are capable of producing viable offspring through self-fertilisation ('selfing'). Species capable of selfing are able to establish self-sustaining populations from a single founding individual.

Life history structure

Most marine invertebrates and fish have a biphasic life history that involves morphologically distinct larval and adult stages. Often, the adult stage is demersal (occurs on or near the seafloor) while the larval stages are planktonic (occurs in the water column).

Three general types of larval development can be characterised among marine animals, reflecting the length of the planktonic stage and therefore the dispersal potential of the larvae:

- Direct development larvae—develop directly within the egg mass or adult and hatch with an almost fully developed adult morphology (such as some marine gastropods). Larvae that develop directly usually have a short pelagic phase or none at all, which results in a low potential for dispersal unless transported by other means (such as by rafting or human-mediated transportation).
- Lecithotrophic larvae—hatch with a yolk sac or other autonomous means of nutrition (such as ascidians). Some species with lecithotrophic larvae are capable of feeding in the water column, but many (such as ascidians) do not, and must settle into the adult habitat before their yolk sac is depleted. Consequently, these species have relatively short pelagic larval durations (hours to days) and do not disperse long distances.
- Planktotrophic larvae—actively feed on other organisms during their pelagic phase. Because they are able to feed during the pelagic phase, planktotrophic larvae generally spend longer in the plankton than do lecithotrophic larvae or direct developers. As a result, they have a greater potential to disperse long distances from the parent population.

Algae have a variety of complex life-history strategies. There is no typical life cycle for algae as a group. Many algae are able to reproduce asexually as a result of vegetative growth or fragmentation. Others produce spores asexually which can germinate into genetically identical individuals, and still other algae have complex life cycles that involve a mixture of sexual and asexual reproductive stages.

Three types of sexual life cycles can be characterised among algae. They are distinguished by the way in which gametes are formed and how fertilisation occurs:

- Gametic life—cycle in species with a gametic life cycle (such as diatoms and species of seaweed) mature individuals are diploid and produce haploid gametes through meiosis. Fusion of the gametes creates a new diploid individual (Weier et al. 1982).
- Zygotic life cycle—in some green algae (Chlorophyta) and primitive red algae the mature plants are haploid and produce haploid gametes. Fusion of the gametes creates a diploid zygote. Meiosis occurs during germination of the zygote, which then produces haploid zoospores that develop into the macroscopic haploid individual (Weier et al. 1982).
- Sporic life cycle—in most large algae, meiosis and fertilisation take place in distinct generations of the plant. One generation (referred to as an 'alteration of generations') is haploid and produces gametes; the other is diploid and produces meiospores (Weier et al. 1982).

In some species, the morphological appearance of the two generations is identical or very similar, while in others (such as *Undaria pinnatifida*) the sporophyte form (diploid stage) and the gametophyte generation (the haploid stage) can be very different and may occupy different habitats.

Dispersal life stages

For many marine species, the juvenile stages (larvae or spores) are the main form of dispersal. Other species form resistant cysts that can lie dormant for long periods before releasing viable individuals. However, significant dispersal may also be achieved by movement of adults. This may occur because the adults themselves are mobile and actively move among different feeding or breeding habitats, or because sedentary individuals are transported by water currents, attached to drifting substrata or as detached adults or fragments.

Time to reproductive maturity

An eradication attempt would have a greater chance of success if the incursion is discovered before the population has an opportunity to reproduce, particularly if the gametes or juvenile life stage is also an important dispersal stage. If the size at reproductive maturity and rate of growth from settlement to maturity are known, it may be possible to infer if reproduction has taken place from the size (or age) distribution of individuals within the population or from the presence and state of reproductive tissue.

Similarly, in some cases it may be possible to estimate how long the population has been present by using known rates of growth and the size (or age) distribution of individuals within the population to determine an estimated time of settlement or recruitment.

Reproductive capacity

The reproductive capacity, or fecundity, of an organism is the number of potentially viable gametes (offspring) that an individual can produce. Some marine organisms are extremely fecund, with a single, successful reproductive event by a few mature individuals resulting in many tens of thousands of offspring, thereby reducing the likelihood of successful eradication.

The fecundity of an organism can have a number of dimensions, including the number of:

- gametes or offspring produced during a single reproductive event
- reproductive events (or cycles) that a mature individual has in a season or a year
- seasons or years that a mature individual can continue to reproduce

1.2.3.2 Life habit

Relevant marine environments for life stages

An effective emergency eradication response involves locating and treating all susceptible individuals, or reducing the infestation to levels that cause irreversible declines in reproductive success or survival within the population (Allee effects). To determine the extent of an incursion, it is necessary to identify the range of marine environments the species can inhabit, including all life stages of the species when these occupy different environments or habitats. Table summarises the range of coastal environments and habitat types that should be considered.

Table 4 Coastal environment variables

Environmental variable	Environment type
Coastal geography	Brackish rivers and creek
	Lagoons and coastal lake
	Estuaries and coastal embayments
	Open coast
Water depth	Intertidal
	Subtidal
	less than 2 m
	2–15 m greater than 15 m
Habitat	Soft sediment (such as muds or sands)
	Natural hard substrata (such as rocky reef, cobbles, shell debris, encrustations)
	Artificial hard substrata (such as wharf piles, pontoons, jetties, buoys, ropes)
	Seagrass meadow
	Algal bed
	Mangrove forest
	Saltmarsh
Coral reef Plankton/nekton	

Environmental tolerances

Knowing the organism's ability to withstand short-term or long-term changes in water temperature, salinity, pH or other environmental conditions can be useful for:

- evaluating the likelihood of that species surviving and establishing self-sustaining populations within Australia
- identifying local environments in which the species may survive
- estimating the likely geographic range over which the species could survive if allowed to spread
- devising methods for treating infested vectors and marine environments.

Life-cycle models, based on temperature tolerance, have been developed for several species to predict their potential distribution range within Australia (Hayes et al. 2007) and are available on the [Australian National Introduced Marine Pest Information System \(NIMPIS\)](#).

When published information about the range of ambient water temperatures and salinity in which the species can survive is limited, it may be possible to infer these by examining the variation in ocean temperature and salinity that occurs over the known geographic distribution of the species. Data on broadscale (1 degree of latitude and longitude) ocean climatology, including in-situ temperature, salinity and dissolved oxygen at standard depths, are available from the [World Ocean Atlas](#).

Susceptibility to environmental toxicants and other stressors

Published information on the susceptibility of the species to other environmental stressors, contaminants or known biocides can be useful in devising methods for treating infested vectors or marine environments. Of most use are studies that report the level of the stressor, in combination with the exposure time needed to achieve mortality of all treated individuals (LD100; lethal dose for 100% mortality of treated individuals).

Stressors commonly used to treat marine pests may be physical or chemical. Physical stressors include:

- temperature (heat or cold)
- desiccation or aerial exposure
- de-oxygenation
- salinity (hypersaline or hyposaline solutions)
- force (such as high-pressure water or air blasting).

Chemical stressors include:

- Oxidising biocides
 - chlorine (gas, or sodium or calcium hypochlorite)
 - bromine
 - active halogen compounds
 - ozone
 - hydrogen peroxide
 - chlorine dioxide
- Non-oxidising biocides
 - aldehydes
 - amines
 - quaternary ammonium compounds
 - organobromines
 - organometals
 - mild acids (such as acetic acid)
 - brine or lime.

1.2.4 What is the potential impact of the species?

Exotic marine species can alter the dynamics of the coastal ecosystems to which they are introduced. The type, magnitude and extent (that is, spatial or temporal) of the change they cause depends on the ecology and life history of the species and the characteristics of the environment and biota into which they are introduced. Evaluating whether such changes are likely to constitute major impacts on the economy, the environment, human health or the amenity of Australian marine resources requires consideration of the likelihood that the changes will occur and of the severity of the consequences.

The amount of information and data available to undertake such evaluations will vary with each pest, and the veracity of the evaluation will vary with the tools and expertise available. Quantitative or qualitative methodologies should be used to assess whether the species may cause major impacts and to estimate the uncertainty associated with the evaluation. If a qualitative assessment is undertaken, expert advice should be used to make judgements about potential impacts and their consequences.

A simple, qualitative assessment of consequences can be undertaken using these steps:

- 1) List the full range of impacts the particular species could have on social amenity, the economy and the environment. A standardised list of 15 impact categories that Hayes and colleagues (2005a) used to rate the potential impacts in Australia of 112 exotic or cryptogenic marine species is shown in Table as a guide, and is consistent with Schedule 2 of the NEBRA.
- 2) Evaluate the likelihood that each impact will be realised. Likelihood values can be estimated as probabilities of occurrence or using a simple five-point scale (Table 6).
- 3) Evaluate the likely severity (consequence) of each type of impact if it were to be realised. A simple scale of consequence level can be constructed for comparative purposes (Table).
- 4) Calculate an overall score potential for each type of impact listed in Step 1, using the evaluations made in Step 2 and Step 3, or use a simple risk matrix table (Table) to identify the likely impact.

Table 5 Categories of the potential effects of marine pests

Impact category	Impact
Social amenity	Adverse effects on human health
Economic	Adverse effects on aquatic transport Water abstraction or nuisance fouling Reduction of aquaculture, commercial or recreational harvest Loss of public or tourist amenity Damage to marine structures or archaeology
Environmental	Detrimental habitat modification Adverse effects on trophic interactions and food webs Domination of or out-competes and limits resources of native species Predation of native species Introduction or facilitation of new pathogens, parasites or other non-indigenous species Alteration of bio-geochemical cycles Induction of novel behavioural or eco-physical responses Genetic impacts: hybridisation and introgression Herbivory

Source: Hayes et al 2005a

Table 6 Example of a risk matrix used for qualitative risk analysis

Likelihood	Consequence				
	Insignificant	Minor	Moderate	Major	Significant
Rare	N	L	L	M	M
Unlikely	N	L	M	H	H
Possible	N	L	M	H	E
Likely	N	M	H	E	E
Almost certain	N	M	E	E	E

Note: Letters represent risk level for a given combination of the likelihood of an event and its consequences: **N** negligible. **L** low. **M** moderate. **H** High. **E** Extreme.

1.3 Sources of information

Information on the distribution, ecology and effects of marine pests can be found via a variety of sources. These include professional scientists, primary sources of scientific literature and online.

1.3.1 Professional scientists

The taxonomic expert or facility that identified the specimen should also be able to supply information on its Australian and global distribution (from published taxonomic literature, museum collection databases and scientific literature). The taxonomist should also be able to supply basic information on the life history and ecology of the species. If these or other details are outside the taxonomist's area of expertise, they should recommend other Australian or international scientists who could provide the information.

1.3.2 Primary sources of scientific literature

Published, peer-reviewed scientific literature may provide a variety of information on the species and its potential affects. However, the amount, relevance, accessibility and quality of information may vary widely among species, depending on how extensively they have been researched overseas. Expert compilation or review may be needed to determine the veracity of the work. Before reviewing scientific literature, it is important to identify the specific information needed so time is not wasted examining extraneous material. Guidance on the types of information needed is provided in [section 1.2.4](#).

1.3.3 Online resources on invasive marine species

Several useful online resources contain summary information on various invasive marine species. These include:

- The Australian [National Introduced Marine Pest Information System](#) (NIMPIS)—a central repository of information on the biology, ecology and distribution (international and national) of invasive marine species. It includes species known to have been introduced to Australian waters and species considered to pose potential for introduction. The information within NIMPIS is also used to support rapid responses to new incursions and to help manage existing introduced species in Australian waters. NIMPIS was originally developed by the CSIRO. The Department of Agriculture assumed responsibility for NIMPIS in 2009.
- [National Control Plans](#)—available for six species: northern Pacific sea star (*Asterias amurensis*), Asian bag or date mussel (*Musculista senhousia*), European green shore crab (*Carcinus maenas*), Japanese seaweed or wakame (*Undaria pinnatifida*), European basket shell clam (*Varicorbula gibba*) and European fan worm (*Sabella spallanzanii*).
- [Global Invasive Species Database](#)—managed by the Invasive Species Specialist Group of the Species Survival Commission of the International Union for Conservation of Nature. It contains information on the ecology, distribution, impacts and potential management of invasive alien species that threaten native biodiversity. It also provides bibliographic references, web links and contact details for experts on the species. The database covers all taxonomic groups from microorganisms to animals and plants in all ecosystems, and includes more than 90 invasive species that inhabit marine or estuarine environments. Information is provided on a number of high-risk species.
- Additional distribution databases that can be used to search information on invasive species include:
 - [Non-indigenous Aquatic Species](#) (NAS) information resource developed by the United States Geological Survey
 - [National Exotic Marine and Estuarine Species Information System](#) developed by the Smithsonian Environmental Research Centre
 - [Guidebook of Introduced Marine Species of Hawaii](#)
 - [CIESM Atlas of Exotic Species in the Mediterranean](#)
 - [The Exotics Guide: Non-native Marine Species of the North American Pacific Coast](#)
 - [National Oceanic and Atmospheric Administration](#)
 - [National Benthic Inventory](#)

- [RAFTS Invasive Species and Biosecurity Programme](#)
- [FishBase](#)
- Marine Invader Tracking and Information System
- [European Network on Invasive Alien Species](#)
- [National Priority Pests: Part II Ranking of Australian Marine Pests](#)—the CSIRO has compiled a database of 1,582 marine and estuarine species that have been transported by human-mediated activities or have human-mediated invasion histories around the world (Hayes et al. 2005a). These species have been classified according to whether they have an invasion history (1,375 species) and whether they are known to be established in Australia (494 species known from Australia, 299 species not established in Australia and 789 species with unknown status). A summary report based on the database ranks 112 species (75 established in Australia and 37 not known to be in Australia) according to their potential for transport in ballast water or as biofouling and their potential for impact if introduced or translocated to Australia. Information on these or other species contained in the database should be sought from the CSIRO Marine and Atmospheric Research group.

1.4 When little or no information is available on the suspected pest

When little or no information is available on an exotic species, a decision to mount an emergency response may need to be based solely on the behaviour the species displays (such as smothering, fouling, establishing monocultures or displacing indigenous species) in the Australian environment in which it is found (Peebles 2004). In such instances, information on closely related species that are functionally similar (for example, similar morphology, reproductive behaviour or feeding modes) may serve as a useful guide to elements of the life history. Information on species from similar genera or families could help determine which elements of life history and ecology are likely to be conserved across related species and may therefore be exhibited by the suspected marine pest.

2 Pest pathways and vectors

Exotic marine species can be spread by a variety of human pathways and vectors (Carlton 2001). Hayes and colleagues (2005a) summarised them into standardised categories for consideration (Table). The likelihood that a species will be transported by any one of these vectors would depend on its life history and its association with marine environments in which the vectors are operating.

Table 7 Categories of potential pest pathways and vectors

Pathway	Description
Biocontrol	Deliberate translocation as a biocontrol agent
	Accidental translocation with deliberate biocontrol release
Canals	Natural range expansion through man-made canals
Debris	Transport of species on marine debris (includes driftwood)
Fisheries	Deliberate translocation of fish or shellfish to establish or support fishery
	Accidental with deliberate translocation of fish or shellfish
	Accidental with fishery products, packing or substrate
Individual release	Accidental as bait
	Deliberate release by individuals
	Accidental release by individuals
Navigation buoys, marine floats	Accidental as attached or free-living fouling organisms
Plant introductions	Deliberate translocation of plants species (such as for erosion control)
	Accidental with deliberate plant translocations
Recreational equipment	Accidental with recreational equipment
Scientific research	Deliberate release with research activities
	Accidental release with research activities
	Deliberate translocation as a biocontrol agent
Seaplanes	Accidental as attached or free-living fouling organisms
Vessels	Accidental as attached or free-living fouling organisms
	Accidental with solid ballast (such as with rocks or sand)
	Accidental with ballast water, sea water systems, live wells or other deck basins
	Accidental associated with cargo

Source: Hayes et al. 2005a

Expert advice and existing literature on the marine pest should be used to identify possible vectors for the species into, and away from, the control area. When limited information is available about human transport of the species, consideration should be given to literature on pathways and vectors of spread for related or functionally similar species.

Two pathways are considered to pose the most serious threat for introducing exotic marine pests into Australian waters:

- discharge of ballast water

- transport of biofouling on seagoing vessels and other maritime infrastructure.

Ballast water can contain the planktonic stages of organisms, free swimming juveniles or adults, fouling organisms attached to the vertical walls of the ballast compartments, and benthic organisms in deposits of mud that accumulate at the bottom of ballast tanks (Carlton 2001).

Fouling assemblages comprise marine organisms such as algae, barnacles, bivalves, tubeworms and hydroids that have attached and are in a sessile life-stage. If these assemblages are well developed, they can also harbour various free-living species such as amphipods, crabs and fish that live in or among the fouling species. Submerged recesses in ships' hulls (such as seachests) and other infrastructure that are protected from water flow are niche areas for biofouling and may contain large accumulations of both attached and free-swimming species (Coutts et al. 2003).

In addition to ballast water and biofouling, other pathways listed in Table are likely to be of importance for translocation of species within Australia.

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 Australia, the control and eradication strategy for marine pests, the policy on decision points and the policy on funding of operations and compensation. This chapter provides 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 Biosecurity 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 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.

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 stand-down phase be implemented
- 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. 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 invasive marine pests

The methods used to control a marine pest incursion will depend on the location and nature of the outbreak. The two possible responses for a marine pest incursion 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 that:

- the species is widely established in open marine environments
- the species is highly fecund and produces broadly dispersed planktonic larvae
- one or more life stages are difficult to detect or treat
- re-establishment of the population is possible following successful reproduction by one or a few individuals.

In practice, both options involve use of 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 clusters of the pest for treatment and to determine the efficacy of the treatment procedure. This information can be used to refine and direct treatment.

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 (C_s), the cost of escape (including likely impacts) if eradication is declared too soon (C_e), 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:

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

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, and the eligible costs of emergency eradication responses shared 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 an incursion by a marine pest depends on early detection and immediate action. Eradication is most likely to be successful in shallow or partially or fully enclosed waterways where the incursion is limited in extent and can be contained effectively. In open coastal waters with moderate-to-high water exchange, emergency containment and control is likely to be possible only for species with limited adult and larval dispersal or which reproduce by vegetative growth or budding from the edges of a colony. Where surveys indicate that an infestation is widespread, eradication action is unlikely to be successful.

Characteristics of marine species, their environment, and the pathways by which they are spread that make them difficult to eradicate include:

- high fecundity
- a microscopic planktonic stage that can be broadly dispersed by water currents, making it difficult to contain
- sequential and sometimes simultaneous hermaphroditism, meaning relatively few individuals can produce large numbers of offspring
- complex life cycles in which adult and juvenile phases inhabit different habitats, so many marine species can be spread by various natural and human-mediated pathways
- the environments in which incursions occur are often turbid harbours, ports or estuaries where detection is difficult
- movements of non-commercial vessels from infested ports or marinas are frequent and often difficult to trace.

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.

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 a marine pest of national concern 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 marine pest species are described in [chapter 2](#).

4.1.1.2 Alert phase

If the initial investigation finds that a marine pest of national concern 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 marine pest of national concern and it 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 an incursion by a marine pest of national concern and it is potentially eradicable, 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—a defined area around an infested area that is subject to intensive surveillance and movement controls on potential vectors².
- control area—a defined area surrounding a restricted area in which biosecurity conditions apply to the entry or exit of potential vectors or specified risk items².

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 the pest 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

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.

- 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* (Cwlth) (superseded by the *Biosecurity Act 2015*) to impose sufficient quarantine measures to limit the spread of the species. The *Biosecurity Act 2015* (Cwlth) can be used in the absence of appropriate state or territory legislative powers and may be used in circumstances, including directing conveyances³:

- 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

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

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. All potentially infested fishing gear, aquaculture equipment or stock should be treated and inspected before removal from the control area.

4.1.2 Incident Manager Incident Manager 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 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. Vectors that have been present in suspect, restricted or control areas should also be treated as high risk. The risk status of vectors may be changed if inspections or surveys find no sign of the pests

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.

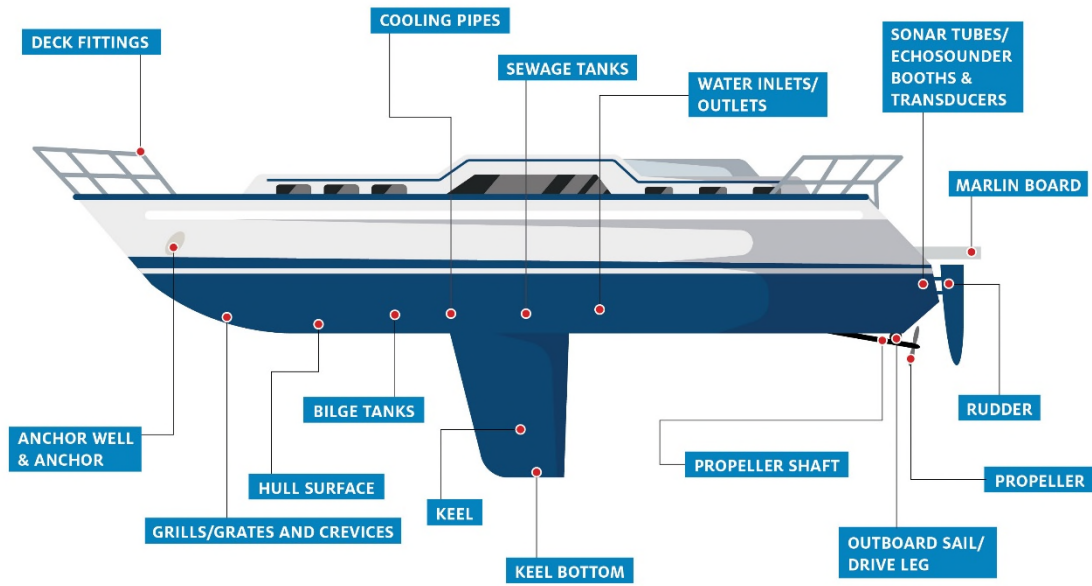
4.1.2.1 Pests transported as biofouling

If the pest can be transported as biofouling or within it, divers should carry out in-water inspection of vessels using a standardised search protocol. If water clarity or regional hazards to diver health make diving unfeasible, alternative approaches to examining fouling communities (such as slipping, use of Remotely Operated underwater Vehicles ROVs or other remote sampling) should be considered. 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 1), 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 1 High-risk niche areas for inspection of biofouling on vessels less than 25 metres



For vessels larger than 25 m in length (Figure 2), 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 2 High-risk niche areas for inspection of biofouling on vessels greater than 25 metres

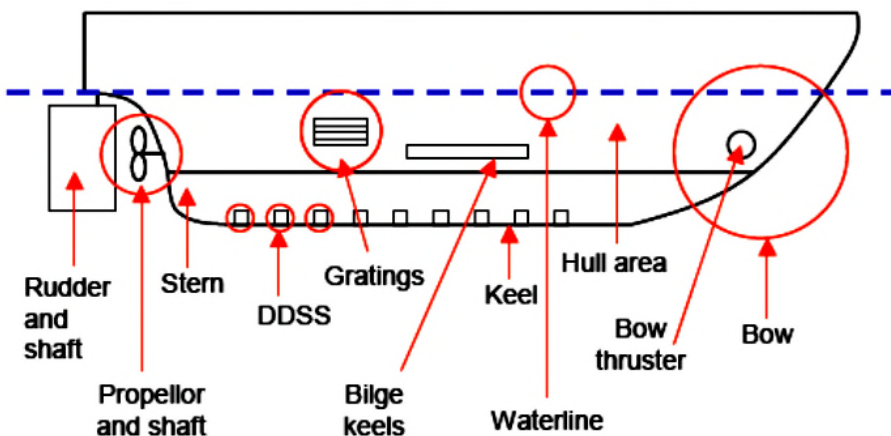


Image: Floerl 2004

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

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 summarises management recommendations for different types of vectors.

Table 8 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 Treat internal seawater systems Manage ballast water Remove from the control area once cleaned
Domestic fishing vessels, ferries, tugs, naval vessels	Clean external submerged surfaces Treat internal seawater systems Manage ballast water
Merchant vessels larger than 25 m departing for other Australian destinations	Inspect and (where possible) clean external submerged surfaces Treat or seal internal seawater systems Manage ballast water
Merchant vessels larger than 25 m departing for international waters	Inspect and (where possible) clean external submerged surfaces Treat or seal internal seawater systems Restrict uptake of ballast water from the control area Restrict ballast discharge within the Territorial Sea Recommend exchange of any ballast sourced inside the control area once the ship is in international waters (greater than 12 nautical miles)
Recreational craft (such as dinghies, jet-skis, kayaks, outboard motors)	Clean external submerged surfaces Clean and dry internal seawater systems Educate users and service agents of risk
Fishing gear and nets	Clean and dry on removal from area Educate users of risk
Aquaculture stock (fouled)	Remove from infested area and destroy
Aquaculture equipment (fouled)	Remove from infested area Clean thoroughly by high pressure (greater than 2,000 psi) water blasting Immerse in copper sulphate solution (4 mg/L) or liquid sodium hypochlorite (200–400 ppm) for 48 hours Rinse in seawater and air dry
Buoys, pots, floats	Clean and dry Restrict removal from the control area 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 Educate users on risks
Flotsam and jetsam	Remove from water/shoreline Dry prior to onshore disposal 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 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 seas⁴, 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 marine pests are 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

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).

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.

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.

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 many fouling species are able to inhabit small, internal piping and water intakes that are not readily inspected underwater, 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 where there are suitable haul-out or dry-dock facilities 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 (2,000 psi or greater) with hot or cold water can successfully remove most fouling organisms on external surfaces of relatively smooth, simple structures, such as vessel hulls. Care should be taken to treat niche areas identified in Figure 1 and Figure 2, and any seawater entry points. Cleaned vessels should be left to dry on the hard stand for a minimum of seven days (Ferguson 2000).

High-pressure water-blasting followed by prolonged (more than seven days) aerial exposure may also be used to treat other fouled structures removed from the infested area (such as mooring blocks, pontoons, floats, fenders). Complex or fibrous structures (such as ropes) will contain crevices and recesses that may not be treated effectively by water-blasting, particularly when the species has cryptic or resistant life history stages. These structures should be destroyed, disposed of to landfill or treated using some other means (such as hot water or chemical immersion).

The organism may be dislodged during haul-out or cleaning of a vessel and could remain viable to 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 move back into the marine environment by direct disposal, run-off, aerosol-drift or any other means. All macro particles (smaller than 1 mm) removed from vessels cleaned out-of-water should be retained and disposed of in landfill (or as biohazard material, if appropriate). All liquid effluent (run-off) from out-of-water vessel water-blasting and cleaning should be collected for treatment in a liquid effluent treatment system. Guidance for identifying vessel cleaning facilities suitable for removal of marine pests can be found in Woods et al. (2007). Approved facilities should also comply with relevant state requirements for waste containment and disposal from slipways, boat repair and maintenance facilities.

Internal seawater systems

Internal seawater systems should be cleaned to the greatest extent possible. The methods used will depend on the susceptibility of the organism to chemical stressors. Treatments that have proved successful for bivalves, which are among the most robust of marine organisms include:

- 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)
- Hot water 60 °C for 1 hour (Growcott et al. 2016)
- copper sulphate solution at a concentration of 1 mg/L for 38 hours (Bax et al. 2002).

The Incident Manager may approve other treatments.

The marine descaler, Rydlyme, dissolves biofouling and is non-toxic and biodegradable. A linear relationship between the level of fouling and the volume of Rydlyme required to digest fouling has been developed for this treatment (Lewis & Dimas 2007). Rydlyme technical application information recommends a Rydlyme:water dilution of 1:1 to be circulated in a closed system for at least four hours, and a freshwater flush of build-up to remove excessive scale (Rydlyme Marine 2004). At this concentration, 14 hours is the recommended application time to dissolve significant mussel growth (Lewis & Dimas 2007).

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

Methods for treating biofouling include wrapping and encapsulation and chemical treatment. Unlike vacuum and brush cleaning, these methods do not remove fouling from the submerged surface of the vessel and moveable structure but aim to kill the biofouling organisms.

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 m 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.

Hull liners manufactured commercially may also be suitable for in-water hull treatments using fresh water or chemical biocides. Custom-made hull liners have a foam flotation collar and are made from UV-treated vinyl material. The liners need to be used in a dock and are not suitable for use with a free-floating mooring. This particular design is limited to ships with a beam width less than 14 ft. (4.3 m) because the tailgate is lifted manually and would become too heavy on larger ships (Aqueal 2007).

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

Pest 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

Various treatments have been evaluated to remove marine pests from aquaculture operations. Pests may be transported either on equipment used to culture marine species (such as ropes, nets, cages, buoys, harvesting vessels) or on the stock itself. Movement of aquaculture stock or equipment from the control area during a marine pest emergency response should be permitted only if it can be demonstrated that steps taken to decontaminate the equipment and stock are able to effectively remove all life stages of the pest (that is, 100% mortality). This is likely to require efficacy trials of the decontamination methods and approval of the protocol by the Incident Manager.

Most studies of methods for decontaminating aquaculture stock and equipment have considered removal of soft-bodied fouling pests, such as ascidians or macroalgae, from cultured shellfish stock or equipment. Different marine pests vary in their susceptibility to physical removal or exposure to toxicants. Species such as bivalves or barnacles, which have strong basal attachments and/or hard exoskeletons that allow them to withstand short periods of exposure to toxicants, are likely to be more resistant to decontamination methods than soft-bodied pests. The effectiveness of any treatments may also be affected by the conditions in which they are applied, including the ambient salinity, temperature, dissolved oxygen, pH, water flow and the size and nutritional status of the treated species.

Treatments that have been used to remove marine pests from aquaculture 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)
 - detergent (less than 3%) (potassium hydroxide) (Gunthorpe et al. 2001)
 - 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).

[Appendix C](#) provides a summary of treatments shown to cause 100% mortality (LD100) of several high-risk marine pests. These results are largely based on laboratory trials of individual or clumped organisms and will need to be adapted to ensure complete mortality on more complex structures, such as ropes or nets, or in treatment of large quantities of equipment or stock. They may also be a

useful guide for selecting appropriate efficacy trials of decontamination methods for other, similar species.

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 marine species (such as shelled molluscs, crustaceans, macroalgae) may be vectors for spread of marine pests. The pests may be transported among, attached to or (in the case of resistant life stages) inside the stock when it is transferred from one location to another. The utility of methods used to decontaminate aquaculture stock will depend on the robustness of the pest and cultured stock to the treatment. For example, adults of thick-shelled bivalves, such as oysters, may be more resistant than the pest to treatment by hot water or high-pressure water blasting. Spat and less calcified juvenile bivalves will not be as resistant to these treatments. In some cases, the cultured stock may be less resistant to the treatment than the pest, making effective disinfection impossible.

Disinfection of bivalves and other aquaculture stock for external hitchhikers is not always effective and must be weighed against the potential environmental impacts of any treatment and their effect on the 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. Elements of the demography of the population may be inferred from the size or age distribution and reproductive state of animals collected during the initial investigations. A population that contains individuals that vary widely in size, or which contains two or more distinct size cohorts, may be indicative of 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 health 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:

[Connie3](#) 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 infestation by a marine pest of national concern in Australia depends on the nature and location of the incursion and the management strategy adopted. Essentially, two management options are available:

- eradication or complete elimination of introduced populations 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 uninfested areas (has ongoing costs and implementation so may have higher cost in the long term).

5.1 Eradication

Eradication is only feasible when:

- the rate of treatment or removal of pests from the infested area exceeds the rate of increase at all population densities
- the infestation is effectively contained and there is no immigration or emigration by the species into or from the control area
- all potentially reproductive animals are at risk of treatment or removal (Bomford & O'Brien 1995).

Eradication is the preferred option only when:

- the pest can be detected and monitored at low densities
- discounted benefit-cost analysis favours eradication over control
- the sociopolitical environment supports using eradication methods.

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.

The planktonic dispersal stages of many marine pests are microscopic and can be spread rapidly, in large numbers, over large distances by tidal and coastal currents. In many circumstances, this will make eradication impossible, because not all life stages of the infestation can be located or effectively contained. Infestations in open coastal waters are likely to be particularly difficult to contain and treat.

Eradication is most likely to be feasible when:

- the area inhabited by the pest is small (less than 1,000 m²)
- 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
- the pest has limited dispersal ability
- the incursion is detected and can be treated before individuals in the population have reached reproductive maturity.

In planning an emergency eradication response, it is important to obtain good descriptions of the nature of the incursion, including the environment in which it is located and the distribution and abundance of the pest. As much as possible, these descriptions should be spatially explicit (that is, geo-referenced) to guide application of treatment methods.

Table summarises the variables that may be used to describe the nature of a marine pest incursion and help define its status.

Table 9 Variables to describe distribution of marine pest incursion

Variable	Distribution level
Area currently infested	Very small (less than 100 m ²) Small (100–1 000 m ²) Medium (1 000–10 000 m ²) Large (1–10 ha) Very large (greater than 10 ha)
Abundance	Low Moderate High
Pattern	Continuous Fewer than 5 patches 5 or more patches
Use of suitable habitat	Low (less than 10%) Moderate (10–50%) High (greater than 50%)
Maturity of organisms found	Juveniles only Adults
Maximum depth of infestation	Shallow (less than 2 m) Moderate (2–15 m) Deep (greater than 15 m)
Maximum depth of available habitat	Shallow (less than 2 m) Moderate (2–15 m) Deep (greater than 15 m)
Turbidity	Clear (visibility greater than 5 m) Moderate (visibility 1–5 m) High (visibility less than 1 m)

Variable	Distribution level
Water exchange in incursion area	Minimal Low High

Source: Crombie et al. 2007

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 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 [Connie3](#)) 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. The Australian Monitoring Design Package (version 2.5) can be used as an aid to determine which species should be targeted within defined habitat types (email the [Australian Government Department of Agriculture](#) for a copy of the package).

The type of sampling method chosen should be based specifically on the species being targeted, the habitat to be searched and the conditions at the site. Expert advice should be sought on the most appropriate survey methods for the species and the location of the infestation. This should include

consideration of the sensitivity of the survey method (that is, the probability that the survey will detect the target species if it is present) and the confidence of detection at the margin of the known infestation relative to the sampling effort (Hayes et al. 2005b).

Habitats and locations within the survey area should be prioritised according to their likely suitability for the pest and the likelihood that it has dispersed from the main centre of infestation. For fouling organisms, artificial structures such as projecting piles, steel facings, ropes and mooring dolphins associated with wharf structures are to be considered high priority. Other surfaces with the potential for colonisation by fouling organisms include breakwaters, groynes, rockwalls, wrecks, hulks, moorings, hulls, aquaculture facilities and natural rocky reefs.

In areas where visibility is less than 1 m, visual survey methods will be inefficient. For soft-sediment habitats, visual surveys may be replaced by other techniques that will effectively sample epibenthic assemblages over large areas (such as benthic sled tows, modified scallop dredge, beam trawls). However, the sensitivity of these methods will vary between pest species and should be estimated to determine the likely uncertainty associated with non-detection.

6 Methods for treating established populations

Methods used to treat established populations of marine pests 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. This chapter summarises treatment options that have been trialled. More details on the efficacy of these treatments can be found in summaries by Aquenal (2007) and McEnnulty et al. (2001a) or in the primary references cited in [Appendix E](#).

The choice of an appropriate method for treating established populations will require consideration of (at least):

- effectiveness of the technique in removing or killing the pest
- practicality of implementation given the nature of the incursion
- acceptability to stakeholders
- likely side effects on ecological processes, the physical environment, public and environmental health and economic values
- legality
- likelihood of success in achieving the management outcomes (including the effects of unmanaged risk)
- cost of implementation
- the degree of uncertainty in both implementation of the technique and its effects.

Methods used to treat marine pest incursions can be divided into three generic types:

- physical removal
- ecological control
- chemical control.

This chapter summarises major considerations for application of different forms of each treatment type. [Appendix E](#) provides a summary of these treatments in both artificial and natural substrates.

6.1 Physical removal

Physical removal includes manual and mechanical techniques and underwater vacuum, suction, filtering, water blasting and trapping techniques.

6.1.1 Manual removal

Manual removal typically refers to collection and removal of the pest organism by hand or by using handheld implements. Manual removal has been used as a rapid response and long-term control option for some introduced macroalgae, molluscs, sea stars and crabs (McEnnulty et al. 2001a). It is very labour intensive (therefore expensive) as it requires location and removal of all individuals within the population. Manual removal requires long-term commitment to surveillance and to continual mopping-up of new clusters of the population as they are detected.

The advantages of manual removal are selectivity for the target pest and limited damage to non-target species. However, as it requires visual detection of the pest it cannot be applied effectively in turbid environments where such detection is impaired. Manual removal is of greatest utility when incursions are small and spatially confined or when they are in sensitive environments (such as marine reserves or areas of high biodiversity value).

6.1.2 Mechanical removal

Mechanical removal entails use of machinery to directly remove the target species, involving techniques such as mowing, dredging, trawling or mopping. Some of these practices are not specific to the pest and can cause considerable bycatch or ecological damage, either through direct disturbance of the assemblages or through modification of habitat (for example, removal of habitat-forming species, increased turbidity, release of toxic chemicals from the seabed).

Mechanical removal is not recommended for fragile species capable of regenerating from fragments (such as many polychaetes and colonial organisms). The limited efficacy and environmental impact of tools precludes them from use as the sole means of eradication; they are best used as part of an integrated pest management plan in association with other treatment options.

6.1.3 Underwater vacuum, suction and filtering systems

Underwater vacuum systems are deployed by scuba divers. They use flexible suction hoses attached to small dredges to suck the target organism from marine sediments or from fouling surfaces. Modifications to the suction head, including use of cutting tools or rotating brushes can be used to dislodge organisms that have strong basal attachments from the treated surface.

Underwater vacuums have been used with mixed results in attempts to control or eradicate some soft-bodied, clonal organisms, including the fouling ascidian *Didemnum vexillum* and benthic populations of the macroalga *C. taxifolia*. They can be used on both natural substrates, as well as on ships' hulls during in-water cleaning operations. These systems are typically designed to contain loose particles, thus reducing the risk of spreading the pest during removal and transport.

Due to the labour-intensive nature and thus high cost of the procedure, diver dredging is most effective against small infestations. When used in fine, muddy sediment or where there is a large quantity of biofouling, dredge filters are easily clogged. In addition, water clarity will rapidly be reduced, thus severely impairing underwater visibility and hence efficiency. Suction dredging is therefore best suited to sites where substrates are primarily sandy.

6.1.4 Water blasting

High-pressure blasting (greater than 2,500 psi) can successfully remove fouling species from hard surfaces. Water blasting has been used to remove established populations of mussels, macrophytes and tunicates from vessel hulls or other hard substrata, as well as from infected aquaculture equipment. It is likely to be effective against a variety of biofouling organisms. The preferred use of this method is to remove infested structures from the water for land-based treatment, as this facilitates containment of organisms and fragments removed by blasting. High-pressure water blasting is a cost-effective and environmentally acceptable way to clean a wide variety of structures. In situ cleaning by underwater blasting should not be considered for an incursion response unless all viable particles (including intact organisms, propagules and unicellular organisms) can be collected.

6.1.5 Trapping

A variety of trap types (baited and non-baited) can be used to target mobile marine species such as decapod crustaceans (crabs, lobsters), fish and sea stars (Aquenal 2007). Trapping programs are simple, quick to initiate and require a minimal level of training and familiarity with equipment.

Trapping has limited collateral impact on the environment and is consequently viewed as a socially acceptable form of pest control. However, its efficacy will often depend on the availability of alternative, natural food sources, which affect catch rates. Although trapping can remove large numbers of (usually) adults from a population, most trapping techniques tend to be highly selective and are therefore effective for only some life stages and sizes or one gender of a population. Because of this, trapping is not an effective eradication tool on its own, but is best used as part of an integrated pest management program along with other treatment methods.

6.2 Ecological control

Ecological control includes water level manipulation, shading and light attenuation, heat treatments, salinity, application of salt, wrapping and encapsulating artificial structures and smothering techniques.

6.2.1 Water level manipulation

Raising water levels in enclosed waterways can be used to drown immersed organisms in surrounding environments. Similarly, lowering water levels in a water body can cause mortality of submerged organisms through desiccation. These tools can be effective control options for marine pests but their application is constrained by the practicalities associated with manipulating water bodies or removing infested structures from the water.

The effectiveness of desiccation as a control method also depends on the species and life history stage concerned, and the relative humidity of the drying environment. Application of these techniques is likely to be restricted to structures that can be removed from the water, or to contained areas where draining of water (drawdown) is feasible.

6.2.2 Shading and light attenuation

Light attenuation can be used to control pest plants. Screens, covers and dyes can change or reduce the amount of photosynthetically available radiation to which the plant is exposed, causing it to die. For plants with large carbon reserves (in underground rhizomes, tubers or other vegetative structures) shading can take a long time to be effective and can be difficult to maintain. Shading may

also not effectively treat all life stages of the plants that have different light requirements. Use of this technique is likely to be limited to enclosed water bodies such as coastal lagoons, barred estuaries or enclosed breakwater harbours, where structures or dyes used to shade plants are able to be kept intact for long periods.

6.2.3 Heat treatments

Flame torches, hot water, steam and other heat treatments can be used as a management tool against biofouling or resistant microscopic stages of pests. The susceptibility of a pest to heat treatment can be affected by ambient temperature and is generally greater if there is a pronounced difference between ambient and treatment temperatures.

Heat treatment is likely to be most effective on soft-bodied organisms and species with thin shells (such as dreissenids), while taxa with thicker shells (such as corbiculid species) will require higher temperatures and/or longer exposure times. Because heat treatment typically requires location and treatment of all individuals, it is most suitable for small, contained incursions and to mop up clusters of individuals. Effective and safe deployment is likely to be limited to depths no greater than 30 m, but only small areas can be treated without the use of multiple dive teams, even at relatively shallow depths.

6.2.4 Salinity

Manipulation of salinity levels (osmotic shock) has been used in several marine pest incursions. It can take the form of immersion of infested structures or equipment in fresh water, manipulation of salinity in enclosed water bodies through re-diversion of fresh or salt water, or through application of large quantities of salt in close proximity to the target organism.

Manipulation of salinity can be an effective technique for treating aquaculture equipment and seed stock and also for in situ treatment of pests where the incursion and treatment can be contained. The major limitation associated with freshwater treatment is that in situ application is restricted to habitats within enclosed environments or structures that can be removed from the water for treatment. It is also likely to have lethal effects on non-target biota.

The efficacy of salinity manipulation depends on absolute salinity change and the rate of change in salinity. The rate of salinity change is likely to be slow for large treatment volumes, so treatments are likely to be most effective for small enclosed areas. The salinity tolerance of a species can vary according to life history stages and may also be affected by other factors (such as temperature, nutrient or oxygen levels). The efficacy of salinity manipulation for marine pests will depend on their ability to withstand prolonged exposure to an altered regimen with no obvious adverse effects. For example, the catadromous mitten crabs, *Eriocheir* sp., are unlikely to be affected by salinity manipulation as they inhabit both freshwater and marine environments and can migrate over land for short distances.

6.2.4.1 Application of salt

Directly applying salt to induce osmotic shock has been trialled in some incursions of the macroalga *C. taxifolia* (Walters 2009). Salt is inexpensive, easy to obtain, safe to handle and can be applied on a large scale with the appropriate resources (such as barge, backhoe). Treatment of small patches of pest populations is possible, but over large scales, this technique becomes less efficient, particularly on steep slopes and high-relief habitats (such as rocky reef). Salt treatment is also not suitable for

application in high energy-environments, since salt would be rapidly dispersed by ocean-generated swell.

6.2.5 Wrapping and encapsulating artificial structures

Black polyethylene plastic bale wrap and plastic silage covers have been used to wrap and enclose fouled structures such as wharf piles, pontoons and jetties. If deployed properly, the wrap restricts water flow within the covering, and respiration of the fouling organisms within the wrap quickly depletes oxygen levels, causing mortality of the organisms.

The method is easy to apply, does not require complex equipment, and is relatively fast acting. Wraps are left on for a minimum of seven days to achieve mortality by deoxygenation, but addition of chemicals (such as acetic acid, sodium hypochlorite) within the wrap can accelerate mortality. Containment of the organism within the wrap reduces the risk of spread. Structures can be treated in situ without interfering with their use, and the probability of damage to private property is low.

Encapsulation has proved a suitable and cost-effective tool but is labour intensive and costly if applied over large areas. Shipping or heavy wave action can loosen and damage the plastic wrappings, reducing the effectiveness and potentially creating an environmental hazard. The workers can also be at risk when deploying the wraps through repetitive bounce diving and handling of hazardous chemicals.

6.2.6 Smothering

Smothering benthic habitats by covering them with plastic, geotextile fabric or burial with sediment (such as dredge spoil) can effectively treat relatively localised infestations. As with encapsulation, smothering can be used to reduce water exchange in benthic habitats creating an anoxic environment that kills most organisms. Smothering is an attractive treatment option due to its ease of application, relatively low costs and minimal impacts on the broader ecosystem; however, non-target organisms in the treated areas will suffer high mortality. High-energy environments make deployment and maintenance of smothering materials difficult.

6.3 Chemical control

An extensive range of chemicals have been trialled in the laboratory for their efficacy against marine pests (McEnulty et al. 2001a). The most prominent example of a successful eradication involved elimination of the black striped mussel (*M. sallei*) from marina facilities in Darwin Harbour using chlorine and copper sulphate solutions (Bax 1999; Bax et al. 2002; Ferguson 2000). This emergency response involved chemical treatment of waters in the entire locked marina. However, other means of deploying biocides are possible.

Chemicals that have been evaluated for their efficacy against marine organisms comprise two forms: oxidising biocides and non-oxidising biocides. Oxidising biocides include chlorine (gas, or sodium or calcium hypochlorite), bromine, active halogen compounds, ozone, hydrogen peroxide and chlorine dioxide. Non-oxidising biocides include aldehydes, amines and quaternary ammonium compounds, organobromines and organometals (Jenner et al. 1998).

Chlorination is the most common form of chemical control used in enclosed water systems because of its economy, availability and wide-spectrum efficacy. Chlorine breaks down naturally and has minimal long-term effects on the environment.

Chlorination does have some inherent problems associated with its use, including:

- the hazards of handling chlorine gas cylinders
- difficulty in maintaining chlorination plants in the operational area
- the non-uniform distribution of residual chlorine at required sites (Rajagopal et al. 2006)
- impacts on non-target organisms.

Chlorine is unstable in water. Exposure to light, elevated temperatures and reaction with organic compounds in the water accelerates the reduction in chlorine concentration so it can be difficult to maintain desired levels. For this reason, it is important to monitor levels of 'free available chlorine' in the treated area. Chlorine in liquid form is capable of causing severe burns and is highly toxic if swallowed or inhaled.

The major constraints for chemical treatment of bodies of water will be 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 management of human health and safety when handling large volumes of chemicals. Legal issues can also influence the ability to administer chemicals in a rapid response context, due to the large number of chemical products available and different legislative requirements between Australian states and territories (Aqueal 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 Medicines Authority.

6.3.1 Containment combined with chemical treatment

Small patches of marine pests can be treated by constructing covered enclosures placed over the clusters of the pest and applying a biocidal agent into the enclosure. This method has been used to treat incursions by the macroalga, *C. taxifolia*, using enclosures made of plastic tarpaulins that were filled with sodium hypochlorite (12% w/v) solution. Because of the need for sealed enclosures on the seafloor, this treatment method is most suitable for sheltered (low-energy) environments. In high-energy conditions, deploying and maintaining containment structures is problematic, as is handling and deploying chemicals.

6.3.2 Direct chemical injection

Direct chemical injection involves injecting individual organisms with a biocide using a pole spear or standard agricultural gun. It has been used to control outbreaks of sea stars. Sodium bisulphate has been identified as the preferred chemical for injection, since it breaks down in sea water and is inexpensive and safe to handle. The method is very specific, since it relies on divers to visually locate and treat individual organisms. It is only suitable for small outbreaks (of up to 4 ha), because of the relatively slow injection rate (120 to 140 injections per hour) achievable through diver application in shallow waters where visual detection is easy.

6.3.3 Poison baits and barriers

Trapping or containment of mobile benthic species may be augmented by deployment of poisoned baits or barriers to the pest. Unlike traps, poisoned baits are not size selective, unless different life stages of the organism have different diets. They can also enhance the efficiency of traps because

dominant animals can be killed before the bait is consumed, negating the effects of 'gear saturation'. The insecticide carbaryl is used in the United States to control burrowing ghost shrimp in oyster culture areas and to control sea lice infestations on marine fish farms. New Zealand authorities have issued regulatory approval for a trial of carbaryl use in lady crab (*Charybdis japonica*) control programs, but resource consent was not given, based on concerns over its possible impacts on non-target species. (Authorisation given to certain activities or uses of natural and physical resources is required under the [New Zealand Resource Management Act 1991](#)) Significant legal and public health issues are associated with handling or deploying poisons in the marine environment and they are not sufficient on their own to effect eradication.

6.3.4 Lime treatment

Deployment of quicklime (calcium oxide) either directly or using porous bags has successfully controlled sea stars in Korea, the United States and Canada. Toxic effects of lime have been demonstrated against echinoderms and crustaceans, but molluscs and macroalgae are generally resistant. Lime is a very attractive form of chemical treatment because it is produced in large quantities for commercial purposes, is relatively inexpensive, and only small quantities are needed to treat benthic organisms. However, environmental concerns are associated with broadscale application of lime, and its effects on marine species and the physical environment remain poorly understood.

6.4 Closed or semi-enclosed coastal environments

Eradication is most achievable in closed or semi-enclosed coastal environments (such as locked marinas, 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 pest population. When resources allow, all habitat potentially suitable for the pest should be treated. When this is not possible, habitats should be prioritised based on suitability for the pest and delimitation survey results.

6.5 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 (deeper than 10 m). Many treatment options described in [section 4.1](#) may be applied to small-scale incursions in these environments, but the main difficulties lie in containing the planktonic dispersal stages and maintaining treatment conditions in a lethal state for sufficient time. The latter requires deployment of structures or application technologies that will allow delivery of chemicals or encapsulation techniques over large areas and which can endure 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 containment and treatment. Trials of steam sterilisation

units on subtidal rocky reefs have shown some effectiveness for treating relatively small areas of habitat, but the efficacy of this technique is compromised in complex topographical environments such as rocky reef habitats.

6.6 Monitoring and ongoing surveillance

Monitoring and surveillance are used to detect new populations or clusters of individuals and to inform eradication and control programs. Active surveillance for the presence of the species 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 declaration of zones free from infestation. 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 and targeted searches, by divers or ROVs, of suitable or treated subtidal habitat within the restricted area or at sites at risk of infection
- systematic and 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 monitoring of recruitment within the restricted area or at sites at risk of infection.

When available, high-throughput DNA sequence markers may be useful for surveillance of planktonic stages of invasive marine species (Blair et al. 2006). Markers with high sensitivity may be able to detect the presence of very small quantities of tissue from the pest, such as plankton samples. However, efficacy trials may be needed to determine the sensitivity and specificity of the primer in batch samples before it can be applied to monitoring.

Appendix A: Specimen preservation and handling

This appendix provides general and taxa-specific specimen-handling techniques. Table A1 is a summary of the preferred and optional narcotising (relaxing) and fixing agents. Information is sourced from protocols for specimen preservation detailed by Hewitt and Martin (2001).

General techniques

A waterproof label containing collection details should be placed inside the collection bag(s) as soon as the specimen is collected. In most climates, biological and sediment samples should be placed on ice or transported to a laboratory for sorting and preservation. In all instances, material should be narcotised and preserved within eight hours of collection. Narcotising and preservation agents are frequently carcinogenic, so a Safety Data Sheet (previously called a Material Safety Data Sheet) should be made available to everyone participating in specimen narcotising and preservation.

General guidelines for specimen handling include:

- All references to formalin in these guidelines mean formalin stock diluted 1:9 with sea water. Formalin stock is formalin with propylene glycol (propane-1-2-diol) mixed 1:1.
- Mix alcohol with deionised water to avoid precipitates.
- The volume of the specimen must be included as part of, not additional to, the water volume when making up solutions. This is particularly important for large specimens or those with large water content (such as ascidians, cnidarians and sponges). Failure to include specimen volume will result in the solution being too weak.
- Always completely submerge specimens in preservative and make sure the specimen is not too big for the jar. If squashed into jars, specimens will distort and, more importantly, will probably not fix properly and may start to decompose.
- Preserving solutions (both formalin and alcohol) used to fix material rapidly become very acidic. If material cannot be processed promptly on return from the field, it is advisable to change the preserving solutions to avoid acidity problems. No material should remain in its initial fixing solution for more than one month.
- Sort specimens and group them according to fixing requirements. Do not mix hard and soft animals; some fragile specimens may be damaged or destroyed.
- Sort soft-bodied animals or unique specimens directly into individual specimen jars.
- Put labels inside a small plastic bag inside the sample bag or jar. The small plastic bag protects the label from chafing, discolouration or other physical damage from specimens during transport and storage. If an outside label is needed, it must be additional to that inside the jar. With very large specimens, attach the label directly to the specimen as well as attaching one on the outside of the bag.

- When labelling specimens during field collecting, be aware that some live animals will eat or otherwise destroy paper labels. Put labels inside a small plastic bag inside the sample bag or jar to protect the label.
- Any material that may be needed for DNA analysis must be either frozen or fixed in 100% ethanol. Collect both sample types if necessary.
- When freezing to relax or store specimens, do not thaw and re-freeze them. Defrost once, photograph if necessary, and then fix in preservative.
- It is important to cross-reference any photographs to the actual specimen photographed. Make sure field labels record this. It is usually best for the person who took the photos to collect the specimens and do the sorting, both in the field and in the laboratory.
- Material fixed properly in formalin can be transported damp, without liquid, if it is in sealed containers. This can greatly reduce weight for transport. Preservative should be replaced as soon as practicable. Delicate specimens and alcohol specimens must have some liquid around them when transported, but the volume can be reduced. Alcohol specimens must have some liquid with them, otherwise they will dry out quickly, even in a sealed container.

Preservation techniques for specific taxa

Many soft-bodied animals such as ascidians and anemones require narcotising before preservation. Narcotising effectively relaxes the animal, preventing the innate defensive mechanisms induced by the shock of placing the animal in preservative.

Anemonies

Photograph and relax live specimen before fixing if possible. Put in jar with enough seawater to allow the specimen to fully expand, then freeze or add menthol or magnesium chloride and leave overnight. Fix in formalin by adding the correct amount of stock formalin to the frozen specimen, making sure it mixes as it defrosts. Store in formalin.

Aplacophora

Best if relaxed first, usually with menthol, magnesium chloride or iced water, then fix in formalin, rinse in water and store in 70% alcohol. Do not leave in formalin for more than a few days, or the spicules will start to dissolve.

Asteroids

Photograph alive if possible. Place live into a dish of sufficient concentrated formalin (mix stock 1:5 with seawater) to cover the sea star and leave overnight. Make sure that sea stars are not distorted before they are put into the fixative. Remove specimens from fixative, place on paper towel and dry in shade. Ensure specimens do not stick to the paper by moving them around regularly (keep their labels with them). When specimens start to change to a pale cream/yellow/orange, put them in a plastic bag with their label. In the laboratory, dry specimens in a microwave oven on high for 30 seconds to 1 minute; cool for a while then repeat until no more moisture is released. Beware of putting sea stars with too much moisture in the microwave as they can explode.

‘Cooking’ sea stars in the microwave will cause them to give off vaporised formalin. Only do this in a well ventilated area, and in a microwave oven that is not used for food preparation. Store dry.

Alternatively, fix in formalin for 24–48 hours and transfer to 70% alcohol for long-term storage. The latter method will preserve the colour in most specimens.

Bivalves

For species with valves that seal tightly, place a matchstick or similar object between valves before fixation to ensure that fixative can reach internal tissues. To get bivalves to gape, either warm until they relax enough, or freeze them. Fix in formalin and store in formalin, except for species with very thin shells, which should be stored in 70% alcohol.

Brachiopods

Fix and store in formalin. To allow best penetration of the formalin it helps to wedge open the valves with a matchstick or similar object. Many species will clamp shut so tightly that this becomes impossible.

Cephalopods

Photograph alive, showing different colour patterns if possible. If live-caught, animals must first be anaesthetised as part of a two-step euthanasia process. Immersion in magnesium chloride (MgCl₂) to achieve an anaesthetic overdose, followed by immersion in 10% buffered formalin (or 70% alcohol) to ensure physical destruction of the brain, is currently considered the most humane method for euthanasing cephalopods. Use a solution of 75 g of MgCl₂ in 1 L of sea water. For tissue preservation, place sample in 70% ethanol or 80% ethanol. Replace with a fresh 70% solution after a day or so, to minimise dilution from tissue water. If possible after collection, pour ethanol off and freeze the sample at –80 °C until required for analyses. Fix in formalin, arranging the arms and tentacles so they are straight and the specimen is not distorted. It may be necessary to use weights or pins to hold the specimen in place. Enough fixative, preferably 10 times the volume of the specimen, should be used to cover the specimens completely. Specimens should be stored in 5–10% buffered formalin (one part concentrated formalin and nine parts seawater) for at least three days. Rinse specimens in tap water and store the specimen in 70% ethanol. For cuttlefish, carefully remove the bone before fixation and store with the specimen after photographing intact animal (it is much simpler to remove the bone without breakage before fixation).

Cnidarian medusa

Photograph live and relax specimens before fixing if possible. Put in a jar with enough seawater to allow the specimen to expand fully, then freeze or add menthol or magnesium chloride and leave overnight. Fix in formalin; do not freeze; store in formalin.

Crinoids

Photograph alive if possible. Fix in formalin, but not for more than two or three days. Store in 70% alcohol. Few species do not fall apart when preserved. Try to keep all fragments together and be aware that crinoids usually carry commensal organisms.

Crustaceans

Photograph specimens alive if possible, particularly shrimps. For commensal species, it is important to also record and, if possible, collect the host. Do not freeze crustaceans unless there is no other option, as they do not fix as well after they have been frozen. Specimens are best fixed alive. Remove hermit crabs from their shells and tube-dwelling species from their tubes before fixing (keep any

tubes or shells). Commensal organisms are often associated with hermit crabs and tube-dwelling species; these may need to be fixed differently to their hosts. If hermit crabs have anemones on their shells, remove the crabs and treat the anemones as detailed above. A pair of multi-grip pliers is useful for breaking open shells to remove hermit crabs. Avoid putting specimens with chelipeds in with other animals, as they may grab and damage more fragile species. It is sometimes preferable to kill large crabs individually and put them into a communal container to fix. Very large specimens may need to be injected with formalin to ensure sufficient fixative reaches internal tissues. Fix in formalin and store in formalin (preferable for all except very small specimens) or in 70% alcohol.

Ctenophores (comb jellies)

Most species are virtually impossible to preserve. It is **essential** that good, detailed photographs and video (if possible) are taken of all specimens. A few of the more solid species, such as *Beroe* spp., and all benthic ctenophores, can be fixed in formalin, and stored in formalin or 70% alcohol. To fix benthic ctenophores flat, the methods used for platyhelminths can be successful. No matter what fixative or narcotising agent is used, most species of ctenophores simply disintegrate within minutes of being preserved, but research suggests that when preserved in 2% acidic Lugol's solution, samples of the invasive ctenophore, *Mnemiopsis leidyi*, stayed intact and were quite stable even after preservation for 105 days (Engell-Sørensen et al. 2009).

Echinoids

Treat large specimens and species with large spines as for asteroids. Place live specimens in a dish and pour preservative over them until the spines stop moving (all spines should be erect). When specimens are removed for drying, puncture the membrane surrounding the teeth with a needle to allow liquid within the test (shell) to drain out. Beware of putting echinoids in the microwave as they can explode. Fix smaller specimens in formalin and store in 70% alcohol.

Echiuran worms

Relax and preserve as for sipunculan worms. Do not freeze, as specimens will disintegrate. In some species, the proboscis is deciduous, and usually breaks off entirely or partially; make sure it is retained. To facilitate later dissection, it can be advantageous to keep echiurans alive in clean sea water for some hours before fixing, to allow them to void sand in the gut. Echiurans exude a chemical toxic to most other animals; beware of this if putting them in containers with other invertebrates when collecting. Fix in formalin and store in formalin.

Ectoprocts

If possible, photograph alive as living colours can be useful identification features. Fix hard species in formalin if possible (not essential) then dry; store dried. Fix soft and lightly calcified species in formalin but do not leave for more than a few days (4 to 12 hours is best). Store in 70% alcohol. In the field, either fix specimens in formalin overnight and transfer to alcohol in the morning, or fix directly in alcohol.

Holothurians

Photograph alive if possible. Always isolate large specimens when collecting, as they often eject their guts when disturbed; tubules tend to adhere to everything they come in contact with. Fix in formalin overnight, then rinse thoroughly in water or fix in 100% alcohol. Store in 70% alcohol. It is important

that holothurians are not left in formalin too long, and are thoroughly rinsed when removed from it, or their skeletal plates will dissolve. These plates are essential for subsequent identification.

Leeches

These must be relaxed before fixing. Use either menthol in sea water or iced sea water overnight, but do not freeze. Shark and ray leeches can be relaxed by submerging specimens in fresh water for a few hours. Transfer to fixative as soon as they stop moving or they will start to rot. Fix in formalin and store in formalin.

Molluscs (general)

Most molluscs can be put straight into formalin to fix, and are usually also stored in formalin (except very small specimens; these are stored in 70% alcohol).

Nemertean worms

If possible, photograph alive, as the colour patterns are distinctive, then relax and preserve as for sipunculan worms. Freezing does not work particularly well with these worms. Nemerteans will often break into pieces when fixed but can still be identified, so all fragments should be kept. Like echiurans, some species of nemerteans exude a toxic chemical and are best kept separate during collecting. Fix in formalin and store in formalin.

Oligochaete worms

Relax and preserve as for sipunculan worms. Photographs of live specimens can be used for subsequent identification. Fix in formalin and store in formalin or 70% alcohol.

Ophiuroids

Photograph alive if possible. Large and solid specimens should be treated as for asteroids. Fix all other specimens in formalin and store in 70% alcohol. Be aware that most species will drop arms. Specimens left in formalin for too long become fragile.

Opisthobranchs (and other reduced-shell gastropods)

These must be photographed alive, as form and colour pattern are very important diagnostic features; if possible, also record food. Specimens must be relaxed before fixing. The best method for relaxing is to put specimen in a jar with enough seawater for it to move around with rhinophores and gills fully extended, then freeze overnight. Add enough stock formalin to frozen jar to make up solution of appropriate strength, and make sure it is mixed as the seawater thaws. If freezing (usually the most effective method) is impractical, use menthol. Magnesium chloride in seawater or iced seawater, overnight will relax specimens. Fix in formalin. Do not leave specimens in formalin for more than one or two weeks, and if possible, only for about 12 hours. Prolonged exposure to formalin will dissolve the mantle spicules or vestigial shell. Store in 70% alcohol.

Platyhelminths

If possible, specimens should be photographed alive. It is important that they are preserved as flat as possible. They can be relaxed using menthol or magnesium chloride overnight, but this is not always successful and specimens often disintegrate. The best method is to freeze a small amount of formalin stock in a jar, then place the specimen on top. It will freeze onto the surface of the formalin, die flat and be fixed at the same time. Add the appropriate amount of seawater to make up the solution. If no other option is available, fix directly in formalin on ice.

Polychaete worms

These can usually be fixed directly in formalin; some larger species may need to be relaxed using menthol or magnesium chloride before fixing. Try to remove tube-dwelling species from their tube to allow proper fixation, but always retain the tubes. This is particularly important with serpulid worms. Many species will fragment when fixed; all fragments should be retained. Fix in formalin and store in formalin or 70% alcohol. In the case of species with calcareous tubes, transfer from formalin to 70% alcohol within 24 hours of fixing.

Polyplacophora

These curl up when removed from their substrate. Specimens should be put onto a flat surface (such as a glass slide or wooden board) and tied flat using cotton tape. Fix in formalin, then untie and store in formalin. Store very small and deep sea species in 70% alcohol.

Sipunculan worms

If possible, relax specimens before fixing so the proboscis is everted. This is best done with menthol or magnesium chloride in seawater overnight. Freezing does not work particularly well for sipunculans. Fix in formalin and store in formalin. Dead gastropod shells often contain sipunculans; check contents before discarding any shells.

Soft corals (octocorals)

If possible, photograph live and relax specimens before fixing. Put in a jar with enough seawater to allow the specimen to expand fully, then freeze or add menthol or magnesium chloride. Leave until relaxed, fix in formalin for up to 12 hours (two to four hours is best). Rinse thoroughly in water, then store in 70% alcohol. If any formalin remains, or the animal is left in formalin too long, the spicules will start to dissolve, and the specimen will become almost impossible to identify. Fix delicate species directly in 100% alcohol; store in 70% alcohol.

Sponges

Photograph live specimens in situ, if possible, to record colours and form. Some species will disintegrate when handled. In the field, freeze specimens, if possible, then fix in the laboratory. If this is not possible, use these procedures to preserve specimen, but do not leave material in formalin for more than 24 hours (8 to 12 hours is best). Fix in either 100% alcohol or in well buffered formalin overnight. Formalin is a better fixative but sponges must be thoroughly rinsed in water to remove formalin before being stored in 70% alcohol. If any formalin remains, or the sponge is left in formalin too long the spicules will start to dissolve and the specimen will become almost impossible to identify. For small or very delicate sponges, fix in 100% alcohol if possible. If formalin is used, do not leave them in formalin for more than two to three hours and rinse in water very thoroughly; store in 70% alcohol.

Tunicates (Urochordates)

Compound, colonial and other gelatinous ascidians must be photographed alive as form and colour patterns are very important diagnostic features. Photograph any other ascidians alive if possible. Large solitary ascidians should be relaxed before fixing; menthol or magnesium chloride in sea water overnight is usually effective; they may also need to have preservative injected into them to ensure adequate fixation. Fix in formalin. Store in formalin or 70% alcohol.

Table A1 Summary of recommended narcotising and fixation techniques

Phylum	Taxa	Photos needed	Narcotising agents							Fixatives		Notes
			None	Fresh water	Chill or freeze	Menthol	Naphthalene	MgCl ₂	70% ethanol	7–10% formalin	Formalin to ethanol	
Annelida	Leeches	No	–	Pref.	Alt.	Alt.	Alt.	Alt.	–	Pref.	–	–
	Polychaetes and oligochaetes	Yes	–	–	–	Alt.	Alt.	Pref.	–	–	Pref.	–
Arthropoda	All	No	Pref.	–	–	–	–	–	Pref.	–	–	Do not freeze
	Barnacles	No	–	Pref.	–	–	–	–	–	Alt.	Pref.	–
	Pycnogonids	No	Pref.	–	–	–	–	–	Pref.	Alt.	–	–
Brachiopoda	All	No	Pref.	Alt.	Alt.	–	–	–	–	Alt.	Pref.	Air dry valves or wedge valves open to allow formalin entry
Chordata	Pisces	Yes	Alt.	–	–	–	–	–	–	Pref.	–	Inject fixative into body cavity of larger specimens
	Urochordates	Yes	Alt.	–	–	Alt.	–	Alt.	–	Alt.	Pref.	Inject fixative into body cavity of larger specimens
Cnidaria	Alcyonaria	No	–	–	Pref.	–	–	Alt.	Pref.	–	–	Must be narcotised, do not use formalin
	Anthozoa: corals	No	–	–	Pref.	Alt.	Alt.	Alt.	–	Alt.	Pref.	Air dry a portion of skeleton
	Anthozoa: anemones	No	–	–	Pref.	Alt.	Alt.	Alt.	–	Pref.	–	–
	Hydroida	No	Pref.	–	Alt.	–	–	Alt.	–	Pref.	Alt.	–
	Scyphozoa and hydromedusae	Yes	Pref.	–	–	Alt.	–	Alt.	–	Pref.	–	Large volumes of fixative
Ctenophores	All	Yes	Pref.	–	–	–	–	Alt.	–	Pref.	–	Large volume of fixatives; most are ineffective
Echinodermata	Asteroids and echinoids	No	Pref.	Alt.	–	Alt.	Alt.	Alt.	–	Pref.	Alt.	Fix in formalin then air dry; ensure sea stars are flat

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Phylum	Taxa	Photos needed	Narcotising agents						Fixatives		Notes	
			None	Fresh water	Chill or freeze	Menthol	Naphthalene	MgCl ₂	70% ethanol	7–10% formalin		Formalin to ethanol
	Crinoids	No	–	–	–	Pref.	–	Pref.	–	–	Pref.	–
	Holothuroids	No	–	Alt.	–	Pref.	Alt.	Alt.	Pref.	–	–	Do not use formalin
	Ophiuroids	No	–	–	Pref.	Alt.	–	Alt.	–	–	Pref.	–
Echiura	All	No	–	Pref.	–	Alt.	–	Alt.	–	Pref.	–	Must be narcotised before fixation
Ectoprocts	Cheilostomes and cyclostomes	No	Pref.	–	–	–	–	–	–	–	Pref.	Short time in formalin; can also air dry
	Ctenostomes	No	Pref.	–	–	–	–	Alt.	–	Pref.	Alt.	–
	All	No	Pref.	–	–	Alt.	–	Alt.	–	Pref.	Alt.	–
Mollusca	Bivalves	No	Pref.	Alt.	Alt.	–	–	–	–	Pref.	Alt.	Air dry valves or wedge valves open to allow formalin entry
	Aplocophora	Yes	–	–	Alt.	Pref.	–	Pref.	–	–	Pref.	–
	Cephalopods	Yes	–	–	Pref.	–	–	Alt.	–	–	Pref.	–
	Gastropods: opisthobranchs	Yes	–	–	Pref.	Alt.	–	Alt.	–	–	Pref.	Air dry after microwaving
	Polyplacophora	No	Pref.	–	–	–	–	–	–	Pref.	–	Tie flat
Nemertea	All	No	–	–	–	Pref.	–	Alt.	–	Pref.	–	Must be narcotised (see detailed methods)
Phoronids	All	No	Alt.	–	Alt.	Pref.	–	Alt.	–	Pref.	–	–
Platyhelminthes	All	Yes	–	–	Alt.	Alt.	–	Pref.	–	Pref.	–	–
Porifera	All	Yes	Pref.	–	–	–	–	–	Pref.	–	–	–
Sipuncula	All	No	–	–	–	Pref.	–	Alt.	y	Pref.	–	–

Pref. Preferred technique. **Alt.** Alternative technique. – Not applicable.

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

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		<p><i>Marine Safety Act 2010</i> (power of Harbour Masters to direct vessels and duty of harbour masters to minimise adverse impacts on environment)</p> <p><i>Port Management Act 1995</i> (where no harbour master appointed, powers to direct vessels and act to minimise adverse effects on the environment)</p>	
Queensland	Department of Agriculture and Fisheries	<p><i>Fisheries Act 1994</i></p> <p><i>Biosecurity Act 2014</i></p>	<p>daff.qld.gov.au/fisheries/</p> <p>www.qld.gov.au/environment/coasts-waterways/marine-pests</p>
South Australia	Primary Industries and Regions SA	<i>Fisheries Management Act 2007</i>	pir.sa.gov.au/biosecurity/aquatics
Western Australia	Department of Fisheries	<i>Fish Resources Management Act 1994</i> (under review)	fish.wa.gov.au/Sustainability-and-Environment/Aquatic-Biosecurity/Pages/default.aspx
Tasmania	Department of Primary Industries, Parks, Water and Environment	<i>Living Marine Resources Management Act 1995</i>	dipwe.tas.gov.au/biosecurity-tasmania/aquatic-pests-and-diseases
Northern Territory	NT Department of Primary Industry and Resources	<i>Fisheries Act 1988</i>	<p>nt.gov.au/marine/for-all-harbour-and-boat-users/biosecurity/aquatic-pests-marine-and-freshwater</p> <p>nt.gov.au/d/Fisheries/index.cfm?header=Aquatic%20Biosecurity</p>

Appendix C: Total mortality treatments for high-risk marine pests

Table C1 Treatments that achieved 100 per cent mortality of marine pests in laboratory conditions

Type of organism	Species	Treatment	Conditions to achieve LD ₁₀₀	Reference
Macroalgae: sporophytes and gametophytes	<i>Undaria pinnatifida</i>	Freshwater immersion	8 hours at 18 °C	(Forrest & Blakemore 2006)
			10 mins at 35 °C	
			45 secs at 45 °C	(Gunthorpe et al. 2001)
			05 secs at 55 °C	
		Acetic acid (4%)	1 min. at 4% in fresh water	(Forrest & Blakemore 2006)
		Air drying	3 days at 10 °C (55–85% humidity) 1 day at 20 °C (55–85% humidity) 8 weeks at 10 °C (over 95% humidity) 6 weeks at 20 °C (over 95% humidity)	(Forrest et al. 2007) (Forrest & Blakemore 2006)
		Bleach solution a	1 hour at 2% concentration	(Gunthorpe et al. 2001)
		Detergent (DECON 90) b	more than 30 mins at 2% concentration, over 18 °C	(Gunthorpe et al. 2001)
Crabs and other decapod crustaceans	<i>Carcinus maenas</i>	Bleach solution a	4 hours at 2% concentration	(Gunthorpe et al. 2001)
		Detergent (DECON 90) b	greater than 8 hours at 2% solution, over 18 °C	(Gunthorpe et al. 2001)
Bivalve molluscs	<i>Mytilopsis sallei</i>	Water temperature	120 mins at 40 °C	(Bax et al. 2002)
			30 mins at 50 °C	
			30 mins at 60 °C	
		Copper sulphate	38 hours at 1 mg/L	(Bax et al. 2002)
		Chlorine	111 hours at 12 mg/L chlorine	(Bax et al. 2002)
			90 hours at 24 mg/L chlorine	
Chlorine/copper sulphate solution	48 hours at 12 mg/L chlorine,	(Bax et al. 2002)		

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Type of organism	Species	Treatment	Conditions to achieve LD ₁₀₀	Reference
	<i>Perna viridis</i>	Water temperature	5 hours at 39 °C 30 mins at 60 °C	(Azanza et al. 2005) (Rajagopal et al. 2003b)
		Chlorine	48 hours at 10–15 mg/L chlorine	(Rajagopal et al. 2003a)
Sea stars	<i>Asterias amurensis</i>	Bleach solution a	1 hour at 2% concentration	(Gunthorpe et al. 2001)
		Detergent (DECON 90) b	more than 2 hours at over 18 °C	(Gunthorpe et al. 2001)
		Quicklime	2 weeks	(Goggin 1998)
		Freshwater immersion	greater than 2 hours immersion at over 18 °C	(Gunthorpe et al. 2001)
Ascidians	<i>Styela clava</i>	Air-drying	more than 7 days at ambient temperature	(Coutts & Forrest 2005)
		Freshwater immersion	more than 24 hours at ambient temperature	(Coutts & Forrest 2005)
		Acetic acid	10 mins at 1% 5 mins at 2% 1 min. at 4% less than 1 min. at 5%	(Coutts & Forrest 2005) (LeBlanc et al. 2007)
		Chlorine (sodium hypochlorite)	12 hours with at least 200 g/m ³ , and free available chlorine maintained at over 20 g/m ³ during this time	(Coutts & Forrest 2005)
	<i>Didemnum vexillum</i>	Chlorine (sodium hypochlorite)	30 secs at 0.5% 2 mins at 0.25%	(Denny 2008)
		Caustic soda (sodium hydroxide)	20 secs at 6%	(Denny 2008)

a Active ingredient 3% sodium hypochlorite. **b** Active ingredient potassium hydroxide at less than 3%.

Appendix D: 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 E: Marine pest management options

Table E1 Physical removal options for marine pest eradication and control in artificial substrates

Removal method	Efficacy and environmental circumstances					In situ removal	Wave energy limitations	Depth restrictions	Target taxa (researched using treatment method)	Comments
	Subtidal reef	Subtidal soft sediment	Intertidal reef	Intertidal soft sediment						
Manual	L	U	L	L	Yes	None	< 30 m	Various, ^a including echinoderms, crustaceans, molluscs, macroalgae	Successful in reducing abundance; unlikely to achieve eradication exc. for small incursions	
Mechanical (harvesting, dredging, trawling, mopping)	U	L	U	L	Yes	None	No	Various, ^a including echinoderms, molluscs	Successful in reducing abundance; unlikely to achieve eradication	
Suction (diver dredge)	L	L	U	U	Yes	Low energy	< 30 m	<i>Didemnum vexillum</i> , ^b <i>Caulerpa taxifolia</i> ^c	Successful in reducing abundance; efficacy reduced on natural substrates	
Suction with cutting head	U	NS	U	U	Yes	Low energy	< 30 m	<i>D. vexillum</i> ^b	Cutting head was not successful	
Suction with rotational brush (confidential report)	U	U	U	U	Yes	Low energy	< 30 m	Various fouling taxa ^d	Preliminary results suggest fouling abundance reduced; eradication not likely	
High-pressure water blasting	U	U	U	U	Possible	Low energy	< 30 m	<i>D. vexillum</i> , ^e <i>Undaria pinnatifida</i> , ^f various fouling taxa ^f	Successful for structures removed from water; unlikely to be successful for in situ operations	
Trapping	U	U	U	U	Yes	None	No	Crustaceans, ^g echinoderms ^h	May be successful in reducing abundance; unlikely to achieve eradication	

Letters relate to the efficacy of the treatment methods: **P** proven. **L** likely. **U** unlikely. **NS** not successful. **a** McEnnulty et al.(2001a). **b** Coutts (2002). **c** J Gilliland, PIRSA, pers. comm. (2007). **d** Hopkins (2006). **e** Coutts (2006). **f** Forrest & Blakemore (2006). **g** Woods et al. (2007). **h** Browne & Jones, (2006a, b).
 Note: For details about suitability of methodologies against a broader range of taxa, see McEnnulty, FR et al. (2001).

Source: Aquenal 2007.

Table E2 Ecological control options for marine pest eradication and control in artificial substrates

Method	Efficacy and environmental circumstances								Target taxa (researched using treatment method)	Comments
	Vessel hulls	Wharf piles, pontoons	Enclosed systems	Aquaculture equipment	In situ	Wave energy limitations	Depth restrictions			
Desiccation/drawdown	P	U	L	P	No	–	–	Various, including <i>Styela clava</i> , ^c <i>Didemnum vexillum</i> ^d <i>Undaria pinnatifida</i> ^b	Successful method; drawdown restricted to enclosed systems	
Heat treatment										
Hot water baths	–	–	–	P	No	–	–	<i>U. pinnatifida</i> ^b	Successful method	
Hot water box	P	L	U	–	Yes	No	< 30 m	<i>U. pinnatifida</i> ^e	Successful method for vessel hulls; requires development for natural substrates	
Steam sterilisation	L	L	–	–	Yes	No	< 30 m	<i>U. pinnatifida</i> ^f	Partially effective; can only treat very small areas	
Shading/light attenuation										
Shading/light attenuation	–	–	–	–	Yes	Low energy	Yes	Macroalgae	Not yet tested in a marine context	
Salinity modification										
Fresh water	U	U	P	P	Yes	Low energy	No	<i>Caulerpa taxifolia</i> ^g	Successful provided organisms can be contained	
Freshwater baths	–	–	P	–	No	–	–	<i>U. pinnatifida</i> ^b	Successful method	
Salt treatment	U	U	L	U	Yes	Low energy	< 30 m	<i>C. taxifolia</i> ^{h, i, j}	Suitable for control; unlikely to be successful for eradication	
Smothering										
Artificial materials (such as PVC, matting)	–	–	–	–	Yes	Low energy	< 30 m	Various taxa including <i>D. vexillum</i> , ^{a, d} <i>C. taxifolia</i> , ^h <i>Spartina anglica</i> ^m	Successful method if integrity of smothering structure maintained	

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Method	Efficacy and environmental circumstances								Target taxa (researched using treatment method)	Comments
	Vessel hulls	Wharf piles, pontoons	Enclosed systems	Aquaculture equipment	In situ	Wave energy limitations	Depth restrictions			
Dredge spoil	–	–	–	–	Yes	Low energy	No	<i>D. vexillum</i> ^a	Successful method	
Wrapping/encapsulation	P	P	–	P	Yes	Low energy	< 30 m	<i>Styela clava</i> , ^c <i>D. vexillum</i> , ^d <i>Mytilopsis sallei</i> , ^k various fouling taxa ^c	Successful method; mortality of pests species can be accelerated via chemical application	
Electric shock										
Pulsed electric fields	U	U	U	U	No	–	–	Various invertebrate larvae ⁿ	Prevented settlement of invertebrate larvae; unlikely to be suitable for eradication	
Electrolysis (chlorine production)	U	U	L	L	No	–	–	Various invertebrate larvae ^o	Prevents biofouling of artificial structures	
Ozone treatment	U	U	L	L	No	–	–	Planktonic organisms, ^p <i>Dreissena polymorpha</i> larvae ^q	Successful in laboratory trials against a range of planktonic organisms	
Acoustic methods	U	U	U	U	No	–	–	Various invertebrate larvae ^f	These methods have shown some promise for preventing settlement of invertebrate larvae, but unlikely to be useful for eradication purposes	
Electromagnetic control (including UV and visible light, radio waves, microwaves)	U	U	U	U	No	–	–	Various invertebrate larvae ^s		
Magnetic control	U	U	U	U	No	–	–	<i>Dreissena polymorpha</i> larvae ^t		

Letters relate to the efficacy of the treatment methods: **P** Proven. **L** Likely. **U** Unlikely. **NS** Not successful. **a** Hopkins (2006). **b** Coutts (2006). **c** Coutts & Forrest (2005). **d** Pannell & Coutts (2007). **e** Wotton et al. (2004). **f** Stuart (2004). **g** Neverauskas & Jordan (2004). **h** Glasby et al. (2005). **i** Westphalen et al. (2004). **j** Rowling & Westphalen (2005). **k** DPIFM (2006). **l** Creese et al. (2004). **m** Hammond & Cooper (2001). **n** Schoenbach et al. (2002). **o** White (1998). **p** Perrins et al. (2006). **q** Boelman et al. (1997). **r** Brizzolara et al. (2003). **s** Morgan et al. (1999). **t** Smythe et al. (1996).

Note: For details about suitability of methodologies against a broader range of taxa, see McEnnulty, FR, Bax, NJ, Schaffelke, B & Campbell, ML 2001.

Source: Aqueal 2007.

Table E3 Chemical control options for marine pest eradication and control in artificial substrates

Method	Efficacy and environmental circumstances							Target taxa (researched using treatment method)	Comments
	Vessel hulls	Wharf piles, pontoons	Enclosed systems	Aquaculture equipment	In situ	Wave energy limitations	Depth restrictions		
Containment/chemical treatment	–	–	–	–	Yes	Low energy	< 30 m	<i>Caulerpa taxifolia</i> ^d	Successful method
Wrapping plus chemicals	P	P	–	–	Yes	Low energy	< 30 m	<i>Didemnum vexillum</i> , ^c <i>Styela clava</i> ^b various fouling taxa ^b	Successful method
Injection	U	U	–	–	Yes	No	Yes	<i>Acanthaster planci</i> ^e	Successful for small outbreaks
Poison baits	U	U	–	–	Yes	No	No	Crustaceans (such as <i>Charybdis japonica</i> ^f)	Successful in laboratory
Poison barriers	U	U	–	–	Yes	No	No	Crustaceans (such as <i>C. japonica</i> ^f)	Unsuccessful in laboratory
Lime	U	U	L	–	Yes	Low energy	Yes	Echinoderms ^a	Successful if applied as a blanket on the substrate
De-oxygenation	L	L	L	–	No	–	–	Various taxa ^g	Variable success; depending on species and life history stage concerned

Letters relate to the efficacy of the treatment methods: **P** proven. **L** likely. **U** unlikely. **NS** not successful. **a** Woods et al, (2007). **b** Coutts & Forrest (2005). **c** Pannell & Coutts (2007). **d** Anderson (2005). **e** Fisk & Power (1999). **f** Browne & Jones (2006a, b). **g** Tamburri et al. (2002).

Note: For details about suitability of methodologies against a broader range of taxa, see McEnnulty, FR et al. (2001).

Source: Aqenal 2007

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

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