Appendix H

NATIONAL CONTROL PLAN

For the introduced marine pest

Northern Pacific Seastar
(*Asterias amurensis*)

1999

Joint Standing Committee on Conservation/Standing Committee on Fisheries and Aquaculture National Taskforce on the Prevention and Management of Marine Pest Incursions

Contents

FOREWORD

Exotic marine species are a threat to the biodiversity and health of Australian coastal marine ecosystems and to the industries and amenities that depend on them. Although the issue of introduced marine species has a long history world wide, the magnitude of the threat they pose to Australia has only become apparent since the mid-1980s. Recent surveys show that there are over 250 introduced marine species in Australian waters, with nearly 180 present in Port Phillip Bay alone (Hewitt et al., 1999). These invaders range from plankton and algae to fishes, occur in every port thus far examined, and have invaded habitats from intertidal rock pools to the open oceanic shelf. In some areas, exotic species now dominate marine communities.

Most exotic species are ‘ecological pollutants’ rather than disasters, but a few are pests and are having major impacts on Australia’s marine ecosystems. As an island continent, Australia’s marine fauna and flora have experienced a high degree of geographic and evolutionary isolation. This combination has lead to high levels of endemicity (>90 per cent in some groups), particularly in the southern temperate regions. Isolation and endemicity may correlate with high invasability and, terrestrial island communities at least, have disproportionately high impacts from invaders. The combination of potentially low biotic resistance and a high inoculation frequency, due to Australia’s dependence on shipping, could well account for why Australia seems to face one ‘pest’ invasion after another.

There is a range of management options available to deal with these pests. Two complementary approaches are needed. First, we need to slow the frequency of introductions and the rate of spread by appropriate vector management during shipping, mariculture and port operations. Second, in the event of pest becoming established we need to develop and apply control options that suit the population dynamics of marine species and the unique social context in which control will have to take place.

The Northern Pacific Seastar, *Asterias amurensis*, is one of the worst recent marine species to invade Australian waters. By the time it was identified in the Derwent Estuary, in 1992, it was already present in the millions and well past the point where a rapid eradication attempt was feasible. In the absence of effective methods for managing domestic vectors, it is not surprising that the Seastar has since spread to another major port complex – Port Phillip Bay. As the Bay is a major transport hub, there is now a high risk of the Seastar being moved to other temperate Australian ports in the near future.

The National Control Plan presented in this document is a coherent, practical plan to minimise the rate of spread of the Seastar and reduce its impacts on Australia’s marine biodiversity and industries. Although focussed on the threat posed by the Seastar, the overall structure of the Plan and underlying strategy are likely to be of general application to other introduced marine pests.

EXECUTIVE SUMMARY

The Northern Pacific Seastar (*Asterias amurensis*) is one of the most nationally threatening of the introduced marine pests to invade Australia. The species has become established in two embayments in southeastern Australia – the Derwent Estuary and Port Phillip Bay - and poses a threat to the waters from Albany (WA) to Sydney.

There is abundant evidence that the impacts of the Northern Pacific Seastar threaten marine biodiversity, including endangered and threatened species and communities, the economic competitiveness of marine industries, including aquaculture and wild fisheries, and shipping and port operations.

Attempts to control Northern Pacific Seastar populations in Australia are ongoing. Eradication of Northern Pacific Seastar is not currently possible, but there are effective ways to contain Northern Pacific Seastar and to lessen the risks of it spreading to new areas.

This Plan outlines co-ordinated national arrangements to manage the risks and impacts from the Seastar over a five-year period by:

?? implementing Northern Pacific Seastar control programs to reduce its spread by focusing on high risk vectors
?? encouraging the development and use of innovative and socially acceptable Northern Pacific Seastar control methods to manage, and if possible eradicate, them
?? educating ocean users and managers and relevant organisations to improve their knowledge of Northern Pacific Seastar impacts and ensure skilled and effective participation in control activities; and
?? collecting and disseminating information to improve understanding of the ecology of Northern Pacific Seastar in Australia, their impacts and methods to control them.

Close links will be set up with other national, Commonwealth and State marine pest management arrangements. The Plan will also be implemented in such a way that the findings that arise can be applied progressively to reduce costs and risk due to the Seastar.

The five-year life of this Plan will consolidate and coordinate the long-term process of managing Northern Pacific Seastar risks to and impacts on biodiversity and marine industries. The main priority during this period is to develop and implement controls on domestic vectors that would otherwise spread the Seastar, while simultaneously developing the options for the Seastar's long-term control and eradication.

The costs of control will be significant. This Plan establishes a framework to maximise the benefit of available resources.

INTRODUCTION

Background

The Northern Pacific Seastar (NPS), *Asterias amurensis*, is one of Australia's worst recent exotic pests. It was introduced from Japan into the Derwent Estuary (SE Tasmania) in the 1980s, and was already well established by the time it was correctly identified in 1992. By 1999, the population had grown to an estimated 28 million individuals, such that the Seastar is by far the largest component of the estuary's biomass. Between 1995 and 1997, four adult Seastars were found in Port Phillip Bay, most probably transported from Hobart by shipping. In 1998, small numbers of juvenile Seastars were found in the Bay; a year later, the Seastar population in the Bay had grown to more than 30 million.

The Northern Pacific Seastar grows rapidly, is highly fecund, forms dense populations, has a very broad diet, and appears to have few, if any, significant native enemies. These characteristics give the Seastar its pest status. As aggregations of the Seastars move across the bottom, they can consume most of the fauna on the seabed, including native seastars. Native plankton may also face significant competition from larval NPS, densities of which in Storm Bay are the highest recorded for seastars anywhere in the world.

Its environmental tolerances suggest the Seastar could eventually spread from WA to central NSW, and inhabit areas from near-shore to depths of at least 100 m. Until recently, its spread has been slow due to circulation patterns in SE Tasmania that keep most Seastar larvae in Storm Bay. This natural barrier has now been breached. As noted above, the Seastar has now established a dense population of highly fecund small adults in Port Phillip Bay. The Seastar now constitutes an enhanced threat to all regional temperate coastal waters.

The seriousness of this threat is evidenced by New Zealand's response to the Seastar. Fearing the spread of the Seastar to its waters, New Zealand invoked its Biosecurity Act and banned the discharge of ballast water from ships from eastern Tasmania and, now, Port Phillip Bay. Without an effective risk management plan, the continued spread of the Seastar in Australian waters will add a significant cost burden to trans-Tasman commerce originating from Australia. In 2001, this burden will spread to Australian domestic shipping, as Australia's national ballast water management system comes into force. Ships originating in ports containing the NPS will be classified as high risk, and required to undertake ballast water treatment if they seek to enter ports elsewhere in southern Australia. The cost of the NPS to Australia's marine industries and biodiversity is already significant, and is growing.

Since 1992, Government agencies have been collecting the information needed to develop options to reduce the impacts posed by the Seastar. A national workshop reviewed all of the options available, identified those likely to be successful, and recommended action (Goggin 1998)

National Workshop - Management review recommendations

?? reduce the rate of the Seastar's spread by shipping and other vectors in Australia, thereby containing its impacts until a general solution is available

?? develop and implement permanent controls on the Seastar's population, possibly leading to its eradication

?? detail the processes underlying those impacts, so that interim measures can be instituted to minimize the costs of the pest.

Given the impacts of the Seastar and the area of Australia at risk, there is an urgent national need for action, before the Seastar spreads to other areas and jurisdictions.

While Northern Pacific Seastar threaten flora and fauna, they also threaten ecological services provided by coastal systems including the fish that support recreational and commercial industries. They could also threaten other key coastal processes, such as nutrient cycling, through indirect effects that are difficult to predict from current knowledge. NPS are also widely recognised as threatening marine industries, including aquaculture, and the economic competitiveness of ports and shipping operations.

Best practice management of Seastars must therefore involve action to reduce the threat not only to flora and fauna, but also to marine industries that are directly or indirectly dependent on a pest free environment.

Northern Pacific Seastars have the potential to impact on jurisdictional waters of Western Australia, South Australia, Victoria, Tasmania, NSW and the Commonwealth. The Seastar's depth tolerances (to 100m) suggests that the species may eventually spread to the mid- and outer continental shelf, and affect an extensive area and fisheries resources of Australia's territorial sea that is managed by the Commonwealth, see Figure 1.

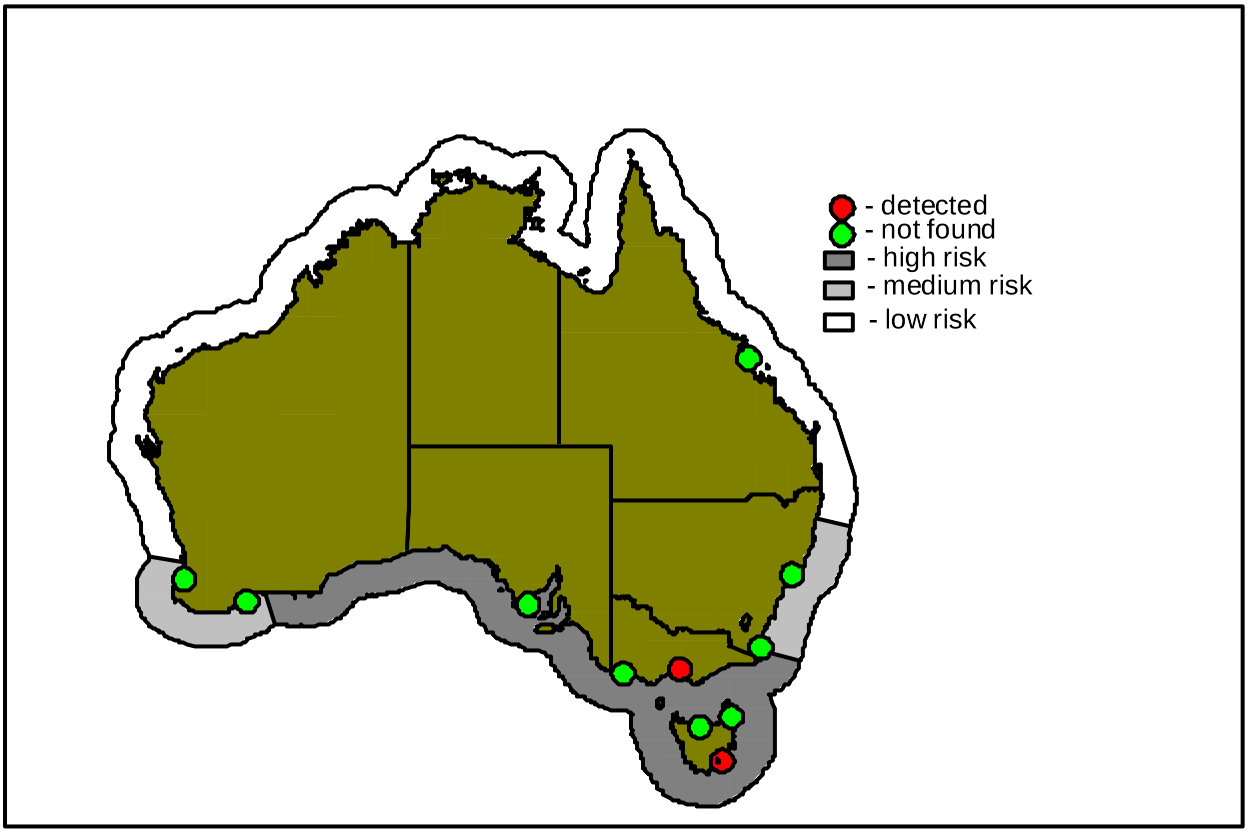

Figure 1. Areas at risk from the Northern Pacific Seastar

This Plan sets out in broad terms the scope for national action and the allotment of resources. It is intended that the Plan will lead to a change in managing the risks and impacts of Northern Pacific Seastar on biodiversity and economic values, producing a more focused and strategic broad scale approach to reducing those risks and impacts.

Impacts of the Seastar on Threatened and Endangered Marine Species and Communities

The principal impacts of the Seastar are through its predation on a wide range of benthic invertebrates. Experimental studies, as well as observations spanning several years, in the Derwent Estuary, show that it consumes a wide range of species, and that it gradually works its way down its dietary preferences until it becomes cannibalistic. Seastar predation appears to fundamentally alter community composition in infested areas, through selective removal of small bivalves and other conspicuous epifauna.

Current understanding of the risks to, and impacts on, significant species and communities are based a variety of studies, but this threat has yet to be systematically assessed across southern Australia.

Beyond its generally predatory activities, the Seastar has been implicated in the precipitous decline in the 1980s of populations of the Tasmanian endemic spotted handfish, *Brachionichthys hirsutus* (Barrett et al., 1996, Ross et al., 1999). In 1996, the handfish was the first marine fish listed in the Commonwealth Endangered Species Protection Act as 'critically endangered', and subsequently listed as such by the International Union for the Conservation of Nature (IUCN). A recovery plan for the handfish is currently being implemented (Bruce et al., 1997).

Evidence for a critical impact of the Seastar on the spotted handfish is indirect. The decline in spotted handfish populations in the Derwent Estuary matched a rapid Seastar increase in the same areas. The Seastar's predatory behaviour led to suggestions that it fed on the slow-moving young of the handfish, ate the large, benthic egg masses (which the Seastar will eat in captivity) or ate the benthic invertebrates on which the handfish frequently lays its eggs (Bruce, et al., 1997).

Gowlett-Holmes (1999) identified two rare echinoderms, both endemic to Tasmania, that were likely to be eaten by the Seastar. *Asterias* may therefore be contributing to the uncertain continuation of these species. The small five-armed seastar, *Marginaster littoralis*, is endemic to the Derwent Estuary, but has not been collected since the 1980s, despite extensive searching for it. Similarly, the small holothurian *Psolidium ravum*, which the Seastar is known to consume, has rarely been collected recently and occurs in areas inhabited by the Seastar.

Other species will inevitably come under threat should the Seastar spread. One community of potential concern is the very unusual fauna of Port Davey, in southwest Tasmania. The dark, tannic stained waters in the bay have resulted in the presence in shallow water of marine species, such as sea pens, and communities more typical of deep-water. This extraordinary community, part of a listed World Heritage Area, exists wholly within a depth range and habitat type well within the tolerance range of the Seastar, and consists of species very likely to be consumed by it.

Notable locations at risk from the Seastar

Notable locations at risk from the Seastar include those valued for their environmental and economic significance. Locations of environmental significance include: areas containing rare or endangered species; areas of importance to the life-cycle of valued fish species; *marine protected areas* (such as at the head of the Great Australian Bight); *World Heritage Areas* (such as in southwest Tasmania) and *Ramsar Sites* (such as the Peel-Yalgorup System in Western

Australia and Westernport in Victoria). Locations of economic significance include the ports and shellfish aquaculture areas across southern Australia.

Developing the Plan

The Plan is based on the following principles:

- Marine pest management is an essential component of ecologically sustainable ocean management including the protection of native marine plants and animals;
- A long-term commitment is essential for effective marine pest management. Marine pest management is an inherent cost in ocean management;
- All natural resource users and managers, including private and public sector, have a duty of care to ensure that their activities do not cause unacceptable damage to the ocean. This duty of care extends to marine pest management as well as addressing other forms of ocean degradation. The users should be responsible for making good any damage incurred as a result of their actions;
- Where there is unacceptable damage and it is not possible to identify the cause of this damage, the beneficiaries should pay for the cost of treatment;
- Prevention and early intervention provide the most cost-effective means of dealing with marine pest invasions;
- Successful marine pest management requires an effective legislative, educational and coordination framework which provides for the participation of all levels of government, managers of public and private sector activities, service industries and the community;
- Government contribution to marine pest management is provided where it produces a public benefit through activities that are technically sound and for which the economic, environmental and social benefits outweigh the costs.

A comparison of marine pest impacts and the effectiveness of government investments in managing the problem

Typically marine pest species establish in an area and then impacts increase as they spread further until they eventually occupy all suitable environments. The typical growth in impact of a marine pest over many years is shown in (Figure 2). Managers are usually motivated to control those marine pests having an obvious impact on their use of the ocean. This generally occurs when numbers and impact are already high (at the right end of the graph, Figure 2). The costs of control may then become an ongoing management investment. By contrast, government intervention is most effective when marine pest numbers are low and infestations are few. The provision of information to raise awareness and encourage early action is an effective contribution that Governments can make in the community interest. Research into appropriate control measures, encouragement of collective action and enforced control are further investments the Governments may make for community benefit. The total impact of a marine pest on the community can thus be minimised by early Government intervention.

Once marine pests have spread to their full geographic range and are well established, the effectiveness of Government intervention in reducing the impact of marine pests is much lower. At this stage the level of activity to reduce impacts should be decided principally by the group or industry affected.

Partners in the implementation of the Plan

Effective marine pest control depends on the development and implementation of working partnerships across State and Commonwealth governments, with industry and the community. Governments together with private and public sector managers, the shipping, wild-fisheries and aquaculture industries, fisheries produce processors and marketers, research organisations and

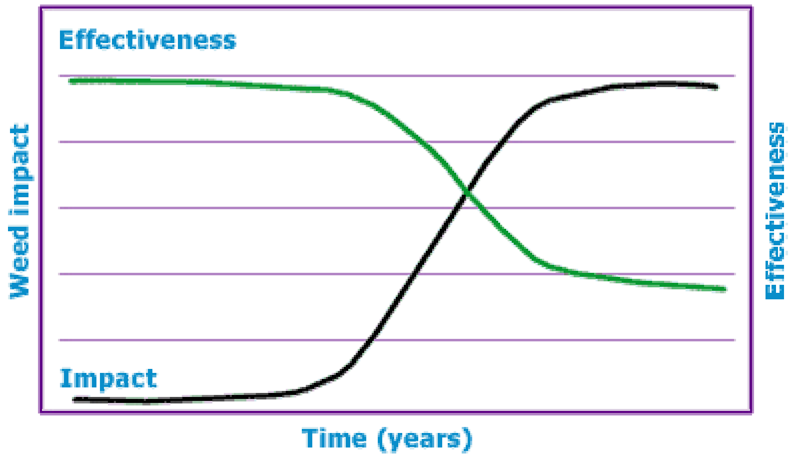

Figure 2. Change in investment effectiveness with increasing Seastar impacts

the wider community have a role to play in achieving environmentally sound and cost-effective marine pest control.

Success will only be achieved if all participants are prepared to allocate adequate resources to achieving effective on-ground control of Seastars at critical sites, and in critical regions, improving the effectiveness of control programs and measuring and assessing outcomes.

However all actions require the cooperation of many others. The level of responsibility varies depending on the action and who is involved. Commonwealth and State Acts provide the legislative base for marine pest control, for those situations in which legislation is a useful tool in achieving the best level of marine pest control.

Cost Sharing Guidelines

Duty of Care: All natural resource users and managers have a duty of care to ensure that they do not damage the natural resource base. The users should be responsible for making good any damage incurred as a result of their actions.

Beneficiary Pays: When it is not possible to identify causes of damage then primary beneficiaries should pay. Contributions from secondary beneficiaries (also known as indirect beneficiaries) will, where appropriate, be negotiated with the primary beneficiaries.

Government Contributes for Public Benefit: Government contributes primarily to activities that produce public benefits. Users, both existing and future, are expected to pay for activities which provide private benefit. (Government may agree to contribute to management activities that produce private benefits where the cumulative up-take of these activities provides significant public benefit or where there is market failure.)

Economic Viability: Before Government contributes to any land and water management activity, the activity must be technically sound and the economic, environmental and social benefits must justify the costs.

Regional Policy and Monitoring: Government will meet the cost of regional planning, regional resource monitoring & assessment, and research & investigation, where they are crucial to sustainable resource management.

Key Australian marine pest legislation

Commonwealth Legislation Environment Protection and Biodiversity Conservation Act 1999 Fisheries Management Act 1991 Quarantine Act 1908 *Western Australian legislation* Environment Protection Act 1986 Fish Resources Management Act 1994 *South Australian legislation* Environment Protection Act 1993 Fisheries Act 1982 Harbors and Navigation Act 1993	*Tasmanian legislation* Environment Management and Pollution Control Act 1994 Living Marine Resources Management Act 1995 *Victorian legislation* Environment Protection Act 1970 Fisheries Act 1995 Flora and Fauna Guarantee Act 1988 Marine Act 1988 *NSW legislation* Clean Waters Act 1970 Fisheries Management Act 1994 Marine Pollution Act 1987

Implementing the Plan

The Plan's conceptual framework is illustrated in Figure 3. The Plan's implementation will be managed by a consortium of senior managers from each of the relevant State and Commonwealth jurisdictions, and the CSIRO. The consortium will meet every six months to review progress, ensure full collaboration and data exchange, and make tactical adjustments to projects that implement the Plan. Key stakeholders will meet annually, to present results as they develop, discuss outcomes and implications, and provide input to the consortium on priority and task revisions. The activities and priorities under the Plan will need to evolve with, and adapt to, changes as they occur. As part of the annual review the Plan's implementation will be subject of an independent audit to ensure the approach is the best possible and to strengthen confidence in the emerging results.

Some vector management controls can be put in place immediately. The full development of the vector controls for domestic translocation will take 36 months. Progressive improvement in the effectiveness of vector controls would be expected as further options are developed and put into practice. It will take five years to develop and select a preferred long-term solution to existing incursions.

Towards the end of five years, the review required by this Plan will examine both the Plan and the success or otherwise of management actions undertaken in implementing it. Recommendations from the review will then be used to prepare a control plan for the following five-year phase.

Effective national management measures should be achieved within the subsequent five years.

The Plan's success will require a long-term commitment of resources by all levels of government, marine industries, and community groups. By taking a measured, stepwise approach, recognising the realistic limitations and opportunities that exist and ensuring that experience and research are applied to further improve management, implementation of the Plan process will ensure a responsible use of public resources and give the best outcome for Australia's southern marine areas. Formal auditing and evaluation by stakeholders and arrangements for the progressive uptake of results are integrated throughout the program.

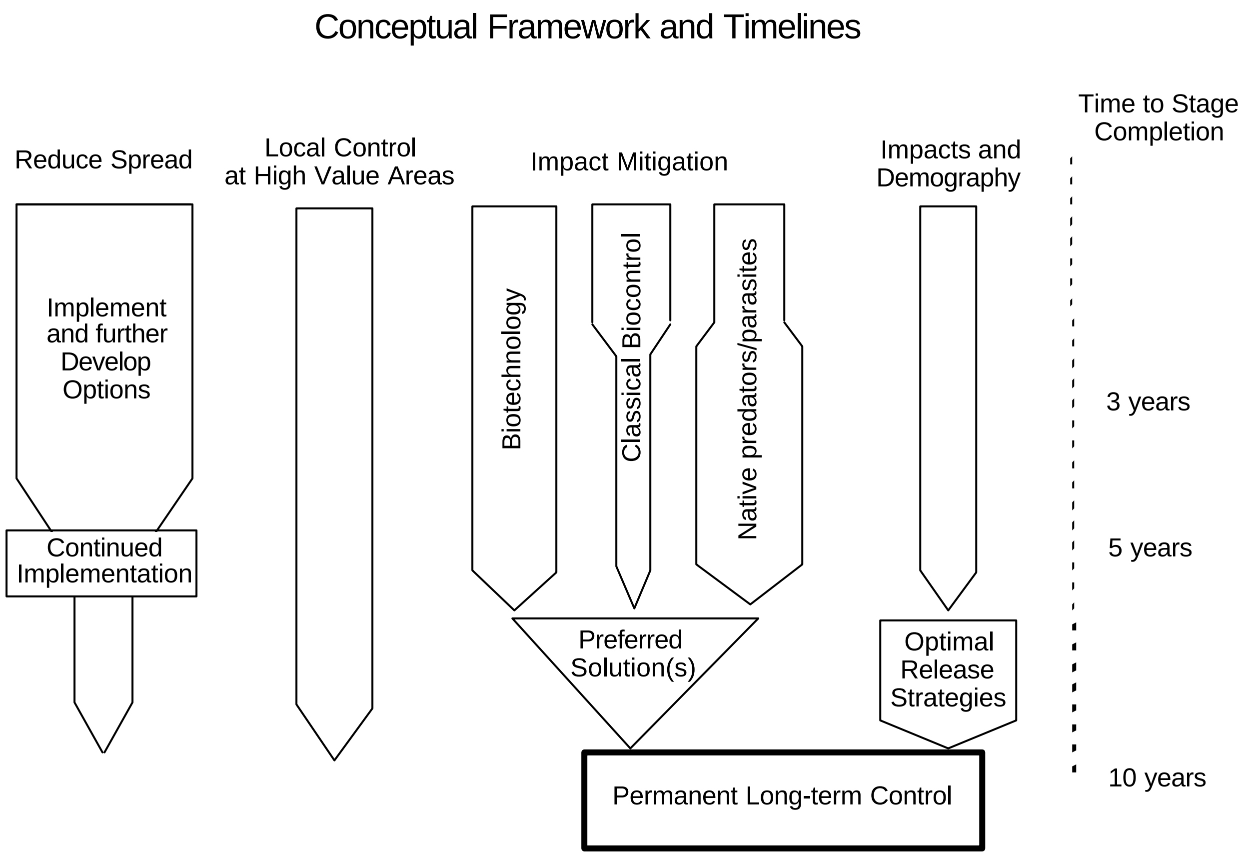

Figure 3. Conceptual framework and timelines for Seastar control

CONTROL MEASURES

Background

Two broadly complimentary approaches to threat reduction are available

?? Vector management – Reduction of the risk of the continued introduction of the Seastar to Australia, and its spread within Australia.
?? Impact management – Reduction of the impact of existing populations, and in the event of an introduction to new area.

Vector management

This is further discussed later in the Plan (see "Developing a National Approach to Controlling Impacts")

Impact management

Action to reduce impacts will need to operate at two scales:

?? Local impact mitigation – actions that reduce Seastar numbers and consequent impacts in localised areas of particular economic or environmental significance. These will be necessary in the current absence of means to eradicate the Seastar or to substantially reduce its numbers, and
?? Regional impact mitigation – reduce Seastar numbers to the extent that complete eradication occurs. Solutions that aim to achieve this are to be developed through this Plan.

Options that lead to complete eradication are often suggested as the more attractive option because, once achieved, they require no further commitment of resources other than for monitoring.

Bomford and O'Brien (1995) argue that the following conditions must apply to achieve eradication:

?? the rate of removal exceeds the rate of increase at all densities;
?? there is no immigration; and
?? all reproductive animals are at risk.

They further state that it is the preferred option only when:

?? all animals can be detected at low densities;
?? discounted cost-benefit analysis favours eradication; and
?? there is a suitable socio-political environment.

These conditions applied for the recent eradication of the black-striped mussel (*Mytilopsis sallei*) in the Northern Territory. Newly developing genetic technology appears likely to satisfy these conditions for the Seastar as well, making eradication a viable long-term strategy.

Goggin (1998) has reviewed available and potential techniques for Seastar impact reduction and these are now outlined.

Physical Removal

Physical removal is the only method currently available for reducing seastar numbers in near-shore coastal environments. A variety of techniques can be employed, involving 'mops', hand collection, and traps.

In Narragansett Bay, lower Chesapeake Bay , over 33 million seastars were removed from a 600ha oyster lease during the four years 1929–32. The most commonly used device for catching seastars was a mop consisting of 12 to 16 large rope yarn brushes, around 1.5m long, attached to a 3m long iron bar. Mops were usually deployed from either side of the towing vessel and were operated in much the same way as a dredge. Seastars were killed by lowering the brushes, with the entangled seastars, into troughs containing hot water. Catch rates using this method were dependent on seastar density but were less than $2.27 m^3 day^{-1}$ (Galtsoff & Loosanoff, 1939). In the late 1930s suction dredges were introduced to remove seastars from oyster beds. These could achieve catch rates of up to $2 m^3 h^{-1}$ in areas where seastars were abundant (Galtsoff & Loosanoff, 1939).

In northern Japan, physical removal of *A. amurensis* is routinely practiced as part of scallop enhancement and culture (Ito, 1991). Seastars are removed prior to scallop reseeding using scallop dredges and traps; 1–3,000 tonnes of Seastars are removed annually from rotational scallop grounds in Nemuro Bay. This reduces maximum seastar densities from around $1.4 m^{-2}$ to $0.4 m^{-2}$ (Ito, 1991).

In 1993, community dives were organised by dive clubs and the Tasmanian Museum to collect Seastars from the Hobart wharves area. The first dive on 10 July 1993 involved 22 divers. More than 6,000 Seastars were collected from a 300m x 20m area next to Princes Wharf and it was estimated that about 60% of the Seastars in the area were removed (Morrice, 1995). A second more extensive community dive on 22 August 1993 collected about 3 tonnes of Seastars (approximately 24,000 individuals) from around Hobart's wharves (Morrice, 1995). Both exercises were mainly to raise public awareness of the problem, and were judged to have a negligible effect on local Seastar densities.

Hand collection, dredging and mopping can effectively and rapidly remove Seastars in localised areas. Hand collection is limited to water less than 12m and is extremely labour intensive. Dredging was not considered practical in the Derwent estuary because it would resuspend heavy metals in the sediments; more broadly, the environmental impacts of dredging on a large enough scale to affect Seastar numbers would probably not be socially acceptable. The impact of "mopping" on sediments was not clear, but is also likely to be significant.

Trapping

In 1994 and 1996, the Tasmanian Department of Primary Industry and Fisheries tested trapping as a means of locally reducing Seastar numbers. Intensive trapping in areas with low/moderate and high Seastar densities failed to control Seastars within the trapped area. In the low/moderate density site 1160% of the original population was removed over a 51 day period; at the high density site 53% of the pre-fishdown population was removed. At both sites, Seastars immigrated rapidly and persistently into the trap area. Mark-and-recapture studies indicated that Seastars were capable of moving at least 20m in 24h.

The potential for using traps to control the migration of Seastars was tested by trapping at the perimeter of an area which was cleared of Seastars by divers. Perimeter trapping, even with traps spaced only 2.5m apart, was not effective in preventing Seastars entering the cleared area. Despite these problems, trapping was judged as the best available control method for chronic infestations, regardless of density or depth.

Commercial harvesting

A financial reward could provide incentive to collect Seastars. For example, in China, *A. amurensis* are sold for about US$1 per Seastar for human consumption. However, there is no market for Seastars for human consumption in Australia, nor any indications of commercially useful bioactive compounds. High levels of metals and the presence of asterosaponins limit the use of the Seastars in fish meal. The Seastars can be composted and used as mulch, but collecting them in sufficient quantities by any technique other than dredging would not be commercially viable. Hence, at present, a commercial use for *A. amurensis* that would significantly reduce its numbers and impacts seems remote. Subsidised fisheries, based on physical removal, are very unlikely to be cost-effective, and were rejected as a viable control option by the National Seastar Taskforce in 1994.

Broadcast Chemicals

The use of broadcast chemicals, and particularly quicklime, as a means of killing seastars has been investigated since the early 1900s. Lime corrodes the carbonate test of the animal, and after 24-48h of contact, produces lesions that often cause death over the following 1-2 weeks. Field experiments resulted in mortalities as high as 70% using circa 200 pounds of quicklime per acre (Loosanoff & Engle 1942). Laboratory studies indicate that the lime remains effective for several weeks after deposition, though at an apparently reduced kill rate. In the field trials, lime was dispersed by shovelling or hosing it into the water; a device designed to spread the material uniformly is described in Loosanoff & Engle (1942), though apparently never constructed. Quicklime has also been tested against *Acanthaster planci* on the Great Barrier Reef, but a considerably lower success rate (28%) was reported (Birkeland & Lucas 1990).

The adverse effects of lime on non-target marine biota and human health appear to be socially and environmentally insurmountable as a means of killing Seastars. Quicklime has severe effects on crabs, larval crustaceans, fish eggs and adult flatfish, and corals, at least. As a severe corrosive, special efforts would also be required to ensure minimum contact with bare skin.

Broadcast trials of other chemicals have also been conducted. All were considered unsuitable because of negative effects on non-target biota and a low kill rate. The broadcast application of chemicals is unlikely to be socially or environmentally acceptable, except perhaps under very controlled and urgent conditions (e.g., a rapid response eradication effort against a highly localised marine pest of national concern, such as the Black-striped mussel in Darwin marinas).

Injected Chemicals

A locally effective method to control *Acanthaster planci* has been the injection, by pole-spear, of toxicants into the seastar. Toxicants trialed, and all proven to be effective, include formalin (in various concentrations), copper sulphate, hydrochloric acid and ammonia. Of those trialed, copper sulphate was recommended as the safest and easiest to use. Kill rates were usually close to, if not actually 100%, depending upon the toxicant used. Environmental impact of the approach was considered slight. There was no indication that release of the poison following the death of the seastar had any significant impact on local biota.

The main limitation of the pole-spear approach is the rate at which it can be applied, typically, less than 100 per hour. Given the millions of Seastars present in both the Derwent Estuary and Port Phillip Bay, this technique is only potentially viable in localised areas in shallow waters. The social and potential environmental implications of leaving large numbers of injected Seastar carcasses rotting on the sea floor would also need to be considered.

Habitat Management

High Seastar densities in the Derwent and Port Phillip Bay may be at least partially a symptom of poor habitat quality, i.e. *A. amurensis* densities may track, rather than drive habitat quality. The Derwent is contaminated with heavy metals, that portion of Port Phillip Bay in which Seastars have established is heavily invaded by other exotic species (eg *Corbula*), both the Derwent and Port Phillip Bay are subject to substantial urban nutrient inputs, and both have been heavily modified due to shore line development and disturbance. Remediation of these degraded and otherwise altered habitats, where practical, may increase native biodiversity and perhaps also the resistance of native marine communities to invasion by Seastars and the impacts of established Seastar populations. Any such remediation is likely to yield a range of additional environmental benefits, but it is important that such remediation funded by the proposed actions are targeted clearly on changes that will directly improve control of Seastars.

Key issues that need to be better understood include the effects of native predators of Seastars, the impacts of in-water waste disposal (such as fish scraps, hull scrapings) on Seastar distributions and reproductive success, and the role of elevated nutrient levels on the survival of Seastar larvae, densities of which in the Derwent are the highest reported for any seastar anywhere in the world. Any or all of these, or similar mechanisms, could be amenable to direct management activity, that could have substantial flow-on effects on Seastar densities. For example, several native predators of Seastars have been identified from laboratory studies. If field data confirm that they do have the real potential to significantly regulate Seastar numbers in the field, subject to consideration of social, economic and other environmental implications, predator numbers could be increased by changes to fisheries management practices or, actively, by supplementing predator populations through mariculture.

While these potential factors may prove important, studies to address them should be clearly focused on starfish ecology and should be approached holistically by determining the factors that control the abundance of Seastars, and then assessing empirically and through modelling the effectiveness of environmental manipulation on Seastar densities and impacts.

Biological control

Biological control involving the introduction of an exotic parasite or disease has been used with varying success against agricultural pests for over 100 years. Typically, a range of putuative control agents have been identified for each agricultural pest. Thus far, options for dealing with the Seastar appear to be more limited. CSIRO has undertaken a preliminary screening of Seastar populations in Canada, Korea, Japan and Russia for potential control agents (e.g., Kuris et al., 1996). The most promising to date is the scuticociliate *Orchitophrya stellarum*, which castrates and may kill male Seastars (Byrne et al., 1997). The parasite appears to be host specific in

Japan, but a similar, if not identical, species infects seven species of Seastar in four genera around the world (Goggin and Bouland, 1997). Whether or not the parasite would infect native Australian seastars is not known, nor is it yet clear what impacts the parasite would have on *A. amurensis* populations if it was introduced. Detailed studies on other possible microbiological control agents are yet to be carried out.

Although Australia has a long history of using biological agents against introduced pests, the use of such an agent against a marine pest would be a world first and would need to proceed cautiously. Importation of the scutiociliate or any other biological control agent for use against *A. amurensis* would require substantial data on threats to native species and efficacy, and could only take place following extensive public consultation and widespread approval.

Biotechnology

Genetic methods are the only approach that currently offers the practical possibility of eradicating the Seastar. Such methods, if feasible, are inherently safe because genetic techniques are inherently species-specific. Several genetic approaches have been suggested, including introducing a fatal weakness into the Seastar population and engineering baits that inhibit its reproduction. The most promising is the development of a gene construct that reduces the Seastar's fecundity. Modelling studies suggest a suitably targeted construct, based on sterile feral technology being developed by the CSIRO, could lead to the long-term decline and potential eradication of the Seastar in Australia.

Such methods require technical development before their feasibility can be realistically determined. There are also major issues regarding social acceptability, that would need to be addressed before any field trials could be undertaken.

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FACTORS INFLUENCING CONTROL OF THE NORTHERN PACIFIC SEASTAR

In developing a national approach to the Seastar's management, a range of issues and constraints need to be considered.

Australia's Leading Role in Managing Marine Invasive Species

Since 1988, Australia has had a national program explicitly to deal with 'ballast water' introductions and their management. Australian government agencies (and particularly the Australian Quarantine and Inspection Service - AQIS) have long recognized the threat posed by exotic marine organisms introduced by shipping, and have lead the agenda at the International Maritime Organization to "do something" about the problem (Paterson, 1994). Domestically, Australia has had a continuous program of research and management into ballast water and other potential vectors since 1989 and undertook world-first studies on ballast water exchange and heat treatment as partial solutions to the "ballast water problem" (Manning et al., 1996). Political review and action through, for example, Ministerial Councils emphasizes the country's continued commitment to managing ballast water as a vector, including support for a nationally integrated management regime, the development of practical management tools, and implementation of a national process for identifying and responding rapidly to new pest incursions and outbreaks (see example ENRC, 1997).

There are two reasons for Australia's leadership in this area. First, Australians are proud of, and protective of, the continent's unique fauna and flora. Australia's geographic isolation has also resulted in the absence of a number of pathogens. Outbreaks of exotic disease, (eg, Newcastle disease and rabies) are vigorously responded to, with strong cultural and political backing. Quarantine issues are significant in Australia. Consequently, threats, in the form of exotic species, have long been recognized as substantial and worthy of concerted remediation. This attitude flows over, though perhaps not consciously, into protecting Australia's marine biota.

Second, the emphasis on introduced marine species is appropriate given the number and apparent impacts of such species in Australian waters. CRIMP currently lists over 250 exotic marine species, which span a range of habitats, bioregions and major taxonomic units. Every port examined has introduced species; in many ports they are dominants; and invasion levels for some ports are similar to those of the major ports studied overseas (Hewitt et al., in prep.) The environmental impacts of these invaders are still being documented, but for many species appear to be substantial (Thresher, 1997; Goggin, 1998).

As a result of these factors, there are strong social and political imperatives to develop and implement programs that defend Australia's marine biodiversity and industries from the impacts of exotic marine species. A coordinated and effectively designed program of pest control is consistent with national approaches to terrestrial pests, and will engender strong support.

A Pest focus for Managing Marine Invasive Species

Over 250 invasive marine species have been recorded to date in Australian waters. The social, environmental and economic impacts of these species varies from readily apparent to difficult to identify in the absence of detailed scientific studies. While we would prefer not have any of these species only a handful appear to be conspicuous pests in terms of their conspicuously apparent: invasiveness and potential for spread, scale of impacts, and extent to which they may be valued for socioeconomic and environmental purposes. The Seastar stands out as a pest with national implications. While the Seastar is the focus for the Plan's actions, the results will directly improve the management of other marine pests and marine invasive species generally.

Prevention and Cure

While prevention is generally accepted as better than cure, both are required and must go hand-in-hand to deal with the risks from, and existing impacts of, the Seastar population. Preventative actions are necessary to reduce the risks of continued introduction of Seastars to Australia from the primary source populations in the Northern Hemisphere and to reduce the risks of the Seastar being introduced to currently unaffected Australian waters from secondary source populations in the Derwent Estuary and Port Phillip Bay. Port Phillip Bay is a major shipping hub, a significant recreational boating venue and an area of projected aquaculture expansion. Consequently, the recent establishment of major Seastar population in the Bay has increased the risk of its spread to other southern Australian waters compared to when it only occurred in the Derwent. Preventative actions will be most effective if the size of the populations in these secondary sources can be reduced or eradicated – the cure. Population reductions also diminishes the risk of the Seastar spreading though natural means. A cure is the only means by which the continued growing impact of existing populations can be managed

Cultural Issues

Two issues routinely emerge in discussing with key stakeholders options for managing marine pests. The first is an attitude of defeatism. Most managers historically have started with an assumption that we simply have to learn to live with the pests. The reasoning behind this attitude flows from the second issue: the social milieu in which control needs to be undertaken differs fundamentally from that for land or freshwater-based control programs (Lafferty and Kuris 1996). There are three critical differences.

First, the ocean is often perceived as 'pristine'; this perception is illogical and easily refuted in principle, but difficult to overturn in practice. Because of it, suggestions to apply a biocide or release a biological control organism sometimes evoke strong, negative reactions, based on a perception that it would degrade the 'pristine' ocean. The second difference is the perceived fence-less ocean, which has two important consequences: because marine organisms are perceived to have unlimited dispersal potential, (1) managers assume that the impacts of local actions are not likely to be localised to the target organism, and (2) a segment of the community assumes that any management action, but particularly biological control, will impact adjacent areas, and more to the point, 'their' adjacent areas (a manifestation of the 'not in my backyard' syndrome). Such an impact, of course, degrades the 'pristine' nature of those areas. The third critical difference is a lingering perception that the ocean is a commons utilized by hunter-gatherers (fishers), which (1) are suspicious of any perceived threat to their independence or fishing success and (2) harvest dispersed resources, which makes it difficult to assign a dollar value to pest impacts or recover cost of control actions. There are obvious exceptions to the last point, such as mariculture operations, pests that affect industrial operations and economic competitiveness of ports and industries dependent on ocean water for coolant, and pests that affect marine protected area, World Heritage and Ramsar listed areas. Lafferty and Kuris (1996) also raised the point that the level of control required for a marine pest may often be less than that required for terrestrial agricultural pests. This is probably true in principle, but may not be true in practice; conservation groups typically push a strong agenda for complete eradication, even if this is currently impractical.

The principal means of addressing such cultural perceptions is to demonstrate, first, that control of marine pests is feasible, and second, that the techniques being developed to deal with a particular species are realistic and show promise. With regard to the first, "rapid response" eradication of the black-striped mussel in Darwin and the green-lipped mussel in South Australia demonstrate that managing marine pests is indeed a practical option, given effective control options and the political will to act. With regard to techniques that can be effective against the Seastar, the actions proposed in this Plan derive from informal consultation with managers, industry, non government conservation organisations and the scientific community, address in a practical way critical processes in controlling the Seastar, and offer feasible long-term options for impact reduction and, potentially, eradication within realistic time spans.

The 'High Seas'

The two areas currently infested with the Seastars are centres for domestic commercial and recreational boat traffic, both of which are essentially unregulated. Quarantining infested areas is difficult, and difficult to maintain once undertaken. The movement between ports facilitates the inadvertent transfer among ports of the Seastar and other introduced marine pests by not only commercial vessels, but also yachts, fishing boats and other small craft.

Two critical steps are required to minimise the rate of domestic transfer among ports.

First, management agencies need to be provided effective technical and legislative tools to manage domestic ballast water movements. A process leading to this outcome is in progress, in the form of broad agreement among the States, Territories and the Commonwealth for implementation by mid-2001 of a single national ballast water management regime. This national regime will be based on domestic implementation of a Decision Support System (DSS), implemented through AQIS, that integrates available information on doner and receival port environmental conditions, ballast water treatment (if any), voyage duration, and the likelihood of a pest being taken up in ballast and surviving the voyage, to assign each vessel/voyage into a risk category. There is broad national agreement that high risk vessels will be required to undertake remediation prior to discharging ballast. Ports are currently developing schedules of appropriate and practical treatment options.

Second, non-commercial vessels are unlikely to be routinely evaluated using the DSS, but the risk of domestic translocation of the Seastar and other pests can be minimised by means of suitably designed and targeted public awareness programs. Such a program in integral to this Plan.

DEVELOPING A NATIONAL APPROACH TO CONTROLLING IMPACTS

Planning Nationally Coordinated Action

Actions to date

Following the Seastar's recognition in the Derwent Estuary in 1992, several steps were taken to initiate a coordinated national response to the pest.

In 1993, the *Asterias amurensis* Steering Committee, chaired by then head of the University of Tasmania Zoology Department, Professor Michael Stoddard was established. This committee's aim was to raise public awareness of the developing problem. It held public meetings on the Seastar and coordinated a community-based dive that collected some 24,000 Seastars in the Derwent and generated national and international interest in solving the problem.

In 1994, the National Seastar Task Force was established, under an independent chair and supported by the Tasmanian Department of Primary Industry and Fisheries (DPIF). Task Force members included representatives from Victoria and South Australia, CSIRO, Tasmanian Museum and Art Gallery, DPIF, the University of Tasmania and the fishing and aquaculture industries. The task force identified priority research areas, and funded projects, ranging from development and testing of Seastar traps to genetic studies confirming the Japanese source of the introduced animals. The Task Force operated until 1996.

In 1998 a national workshop reviewed what was known about the impacts of the Seastar in Australian waters, evaluated options for impact reduction, and recommended research directions and priorities (Goggin,1998). The workshop identified six research priorities:

?? ascertain the role of *Asterias amurensis* in the marine community, to determine the extent to which it causes or tracks environmental variability.
?? develop methods to minimise the spread of the Seastars on mussel ropes and other aquaculture facilities
?? determine the risk of vessels spreading Seastar larvae from the Derwent to other Australian ports and develop methods to reduce this risk
?? develop a population dynamics model for *A. amurensis* in the Derwent, that could be used as a basis for scenario testing of control options
?? seek biological control agents for the *A. amurensis* (with particular emphasis on Australian native predators and parasites)
?? review the options for genetic manipulation of *A. amurensis*

The actions listed above and the ongoing experience gained by CRIMP, TAFI and MAFRI have helped establish the basis for this Plan.

National Strategies

Actions in two broad areas – vector management and impact management – is therefore needed in order to manage the risks to and impacts on Australia's marine biodiversity and industries arising from the Seastar .

Vector Management - Constraining the rate of spread

Preliminary research identifies three high risk vectors for domestic spread:

1. Transfer of ships ballast water - live Seastar larvae have been collected from the ballast tanks of ships originating in the Derwent
2. Transfer on ships hull and gear fouling - fully adult and conspicuously fecund Seastars have been removed from the sea-chests of commercial vessels crossing Bass Strait
3. Transfer on aquaculture equipment - small juveniles routinely inhabit mussel ropes, oyster spat trays and other mariculture facilities, which are often moved between areas.

Initiatives to reduce the risk posed by these vectors include: effective domestic ballast management, with supporting legislation; development of specific protocols to reduce the risk of transporting larval Seastars in domestic ballast water, to ensure effective cleaning and disposal of Seastars from sea chests (or other hull fouling), and to depurate mariculture products and equipment from infested areas; and awareness and extension programs that ensure the effective uptake of risk reduction protocols. The underlying approach is to identify high risk activities (e.g., ballast up-take patterns, specific routes, or areas of particularly highly infested mussel ropes) that will be targeted for management actions, while reducing risks across the board by uniform application of practical management options.

Impact Management

Once Seastars are established in an area, with the exception of localised high value areas, there is currently no 'off-the-shelf' technology can be applied to reduce their impacts in a socially, environmentally or economically acceptable way. Three approaches to biologically controlling the Seastar can potentially be used for broad-scale management of impacts from established populations:

1. biotechnology (genetic modifications of the Seastar or its prey to reduce fertility or increase mortality)
2. importation of exotic parasites or diseases (classical biological control)
3. enhancement of native Australian predators or parasites and/or habitat restoration

These approaches are not completely independent. There is overlap in information required for effective implementation of each of them, and all three provide insights into managing marine pests other then the Seastar, irrespective of their ultimate utility against the Seastar. The three approaches will therefore be developed concurrently. Realistically, it will take five years of research and development effort to bring any of the three to the point of effective application, if preliminary investigations do forecast that they are likely to provide an effective and feasible management tool. The relative balance of effort will therefore be assessed at least annually, on the basis of results as they develop, and to focus resources on those activities that hold most promise for reducing the Seastar's impacts to an acceptable level.

Concurrent studies will include:

1. Targeted impact studies on existing affected areas, Derwent Estuary and Port Phillip Bay, to establish minimum targets for cost-effective pest control
2. Describing the demography (recruitment, abundance and distribution) of the two extant populations to provide input to population models that test pest control scenarios and establish the baseline for evaluating the effectiveness of impact-mitigation .

CONTROL OBJECTIVES AND ACTIONS

The aim of this Plan is reduce the impacts of Seastars in infested areas and the threat of its spread to currently uninfested areas in order to protect Australia's marine biodiversity, including endangered and threatened species and communities, and economic competitiveness of marine industries, such as aquaculture, wild fisheries and shipping and port operations.
These aims will be achieved by identifying high risk sites and habitats and applying currently available methods for short-term control of the Seastar, by developing long term solutions to the Seastar problem, and by developing and implementing interim measures to constrain the spread of the Seastar to un-infested areas prior to the availability of long-term control options. The key performance indicators will be the development and implementation of a Seastar-specific control measure, the prevention of the spread of the Seastar to currently un-infested areas, and the recovery of marine communities currently affected by the Seastar.

Plan objectives

1. Prevent the spread of *Asterias amurensis* in Australian waters beyond its current distribution in the Derwent Estuary and Port Phillip Bay
2. Develop methods for permanently reducing the impacts of, if not eradicating, *A. amurensis* in Australian waters
3. Minimise the impacts of existing *A. amurensis* populations on economically significant areas and resources (including fisheries) and environmental sensitive areas containing threatened species and communities or identified as Marine Protected Areas, or covered by national and international arrangements such as the Ramsar convention, or World Heritage Convention.
4. Improve knowledge of the impacts of *A. amurensis* on native Australian marine biodiversity and threatened and vulnerable species and communities
5. Communicate the results of the Plan's actions to management agencies, marine industries and the public
6. Effectively coordinate control activities

Cost-effective and efficient control measures will be integrated with other relevant natural resource management activities, and will be applied through regionally coordinated management partnerships involving industry, community groups and all levels of government.

To achieve control, actions in five key areas are prescribed:
1. Facilitate the use of practical methods to reduce the risk of spreading the Seastar in Australian waters
2. Implement Seastar control in areas of high conservation priority;
3. Encourage the development and use of innovative and humane control methods for Seastar management that do not have associated unacceptable social, economic or environmental implications.
4. Collect and disseminate information to improve understanding of the impacts of the Seastar in Australian waters and the methods used to control them; and
5. Educate stakeholders to improve their knowledge of the impacts of the Seastar and ensure skilled and effective participation in control activities

1. Preventing the Further Spread of the Seastar

Objective 1. Prevent the continued spread of the Seastar in Australian waters

In the long-term, natural spread of the Seastar is inevitable. Seastars of this species produce large numbers of planktonic eggs and larvae, which drift in the ocean's currents for up to three months, before settling to the bottom as juvenile Seastars. Nonetheless, the species currently occurs only in semi-enclosed areas, such as the Derwent estuary and Port Phillip Bay, where current patterns may prevent large scale dispersal of larvae. Retention of larvae in nearshore areas may contribute to dense Seastar populations in such areas.

The greatest immediate threat of spreading Seastars beyond the Derwent and Port Phillip Bay is inadvertent human transport – in ballast tanks, in sea chests, on ships hulls, and in mariculture shipments and the transfer of mariculture equipment between areas. The risks of transferring Seastars can be greatly reduced by implementing management practices that are progressively improved by technical studies that maximise their effectiveness .

Managing the risks of new Seastar outbreaks is assisted by the development of effective monitoring programs in currently un-infested areas, and a contingency plan to effect rapid eradication of small numbers of the Seastars should they be discovered.

Actions

Implement a domestic Decision Support System for ballast water management, to identify and require risk reduction protocols be used by vessels deemed at high risk of carrying viable Seastar larvae in ballast water.

Identify mechanisms that enable the Seastars to attach to hulls and implement actions to reduce the risk of attachment

Use industry education programs to encourage ships to regularly clean seachests and to safely dispose of material collected in them.

Develop cost-effective means of depurating mariculture equipment and products, and encourage widespread use of these methods through education and legislation.

Develop and implement targeted monitoring programs for Seastars in un-infested areas, including the provision of suitable identification material and the development and implementation of a targeted awareness campaign.

Develop contingency plans for 'rapid response' eradication efforts in the event of a new Seastar population being identified in previously un-infested areas based on currently available techniques, including physical removal by hand, mopping, trapping and small-scale chemical treatment.

2. Seastar Control

Objective 2. Develop methods for permanently reducing the impacts of, if not eradicating, *Asterias amurensis* in Australian waters

Other than for small areas and short periods there are no currently available methods for reducing Seastar numbers or impacts . The large numbers of the Seastars, their high fecundity and their spread across hundreds of square kilometres of sea bottom virtually dictates a long-term control strategy based on biological control. Scoping studies have identified several potential control options, based on enhancement of native predators, importation of an exotic Seastar-specific disease or parasite, and the development of novel genetic technologies that have the potential to eradicate the pest.

Enhancement of native predators

The use of native Australian species as control agents is inherently less risky than importing a foreign agent. Thus far, screening of Seastars in Australia has found no significant Australian parasites or diseases, but several Australian species are now known to eat the Seastar, although the Seastar is not the preferred food of those identified to date. Thus far, there is no indication of strong predatory impacts of well established populations (though there is evidence of predation along the margins of extant distributions, which may be constraining rates of spread). As the Seastar spreads into new areas, however, it will encounter new suites of predators, parasites and diseases, which might offer possibilities for control. The extent to which any these agents could be enhanced to target well established Seastar populations, and their real potential to significantly affect Seastar populations, must be determined on a case-by-case basis.

Action

Conduct studies in and around the Derwent Estuary and Port Phillip Bay to determine the effects of native Australian predators and diseases on the Seastar

Develop the consultative processes and any legislative processes necessary to evaluate and decide on the merits of proposed management approaches relating to enhancement of native predators.

Classical biological control

This is based on the importation of predators, parasites or diseases from the target organism's native range. CSIRO has carried out initial surveys for potential control agents in Japan, Korea, Russia, Canada and Europe (the last two examining close relatives of the NPS) over the last four years. One strong candidate has been identified to date. The ciliate, *Orchitophrya stellarum*, is a parasite that destroys the gonads of male Seastars . Infection levels in the Seastars native range are patchy, but can exceed 80%. The key issues with this control agent are safety (will it infect native Australian Seastars?) and efficacy (under what release scenarios will it result in reduced Seastar abundance?). Safety trials are paramount, and need to be conducted overseas and then, if successful, in much greater detail in quarantined facilities in Australia, so that risks to native species can be properly and accurately determined. Overseas observations indicate that the natural ciliate-Seastar dynamic is unlikely to reduce Seastar numbers substantially. However, the ciliate is simple to rear in captivity, so that augmentative releases are very feasible and could lead to infection rates in Australian populations reaching nearly 100%, that is, nearly complete sterility of males. The University of Tasmania is examining the fertilisation dynamics of the Seastar, to determine the threshold levels of infection needed to reduce Seastar recruitment and population size.

Actions:

Complete safety and efficacy trials for the parasitic ciliate *Orchitophrya stellarum* overseas, and, if justified, in greater detail in containment facilities in Australia

Survey Seastar populations along the margins of its native range for other possible biological control agents, and test the safety of the most promising agents against native Australian Seastars

Develop the legislative and consultative processes necessary to evaluate and decide on the merits of releasing a biological control agent into the Australian EEZ.

Biotechnology

The CSIRO, in conjunction with the Australian Defence Force Academy, has evaluated the fate of pest populations subjected to several different, technically feasible genetic controls. Control options were examined under various stocking regimes and different rates of introgression into the pest populations and included: programmed (age-specific) mortality; inducible mortality (triggered artificially or by extreme environmental events); addition of sterile males to the population; and sex ratio biasing. The options will be refined as more information on Seastar population genetics develop, but already demonstrate that any of several genetic solutions could lead to massive permanent reductions in Seastar numbers and, in some scenarios, complete eradication. The short life span (5-6 years) and rapid maturity (1-2 years) of the Seastar means that such techniques could have dramatic impacts on Seastar numbers within only a few years of their implementation. No effort has thus far been put into building the genetic constructs for the Seastar, but the options build on those being developed by the CSIRO for application to carp and feral Pacific oysters and can draw on extensive background information available on echinoderm genetics and embryonic development (the closely related and genetically similar sea urchins are model organisms for developmental genetics).

Actions

Investigate and develop genetic approaches to eradicating the Seastar

Develop the legislative and consultative processes necessary to evaluate and decide on the release of GMO technology for pest control in the Australian EEZ

3. Interim Impact Reduction

Objective 3: Minimise the impacts of existing Seastar populations on economically significant areas and resources (including fisheries) and environmental sensitive areas containing threatened species and communities or identified as Marine Protected Areas, or covered by national and international arrangements such as the Ramsar convention, or World Heritage Convention.

Interim procedures need to be developed and implemented to reduce the threat due to the NPS to Australia's marine biodiversity and environmental services, in order to prevent irreversible damage pending the development of long-term control options. The broad diet of the Seastar and the high densities it can reach constitute a uniquely dangerous combination for Australia's temperate marine biota. Similarly, fisheries and aquaculture operations in areas infested by the Seastar are at risk of significant economic damage.

Actions

Support studies that detail the interactions between the Seastar and threatened marine species and communities, and develop species-based action plans for each of those determined to be at significant risk.

Identify the risks to significant habitats, areas and environmental services (such as critical de-nitrification and nursery areas, mariculture farms and ports) and develop and implement impact reduction programs based on currently available control methods, such as physical removal by hand, mopping and trapping commensurate with the scale of that risk.

Assess the known and probable impacts of the Seastar on Australian coastal fisheries and modify management procedures accordingly to minimise interim economic impacts

4. Improved Knowledge

Objective 4: Improve knowledge of the impacts of *A. amurensis* on native Australian marine biodiversity and threatened and vulnerable species and communities

Current knowledge of the biology of the Seastar is sparse, based on two, as yet incomplete doctoral projects underway in Tasmania, a few short-term undergraduate projects, unpublished work by CSIRO and projects by MAFRI in Port Phillip Bay. These projects focus on diet, distribution and some aspects of reproduction, including larval identification. Year-to-year variability in Seastar numbers, distribution and impacts are largely unknown, as are the environmental factors that constrain the abundance of the Seastar or its impacts on Australia's native biota.

These are critical data for ensuring the that risk management is commensurate with the scale of the threat posed by the Seastar and also for optimising interim and long-term control strategies and for evaluating the effectiveness of those controls once implemented.

Actions

Establish graduate scholarships for studies on the Seastar's ecology

Establish a baseline and conduct follow-up surveys to determine the distribution, abundance and condition of established Seastar populations.

5. Education

Objective 5: Communicate the results of the Plans actions to management agencies, marine industries and the public.

The success of this Plan will depend on cooperation between all key interest groups, including marine industries, community groups, the scientific community, local government, State and Territory conservation and pest management agencies and the Commonwealth Government and its agencies. Ensuring that marine managers and community organisations are skilled and effective participants in control activities, and improving their knowledge of the impacts that the Seastar has upon native species and communities and the economic competitiveness of marine industries and the social benefits provided by healthy marine resources, is an essential component of the Plan.

The Plan will document the significant advances in knowledge, techniques and practice for abating the threat to endangered and vulnerable species and ecological communities, and the economic competitiveness of marine industries posed by the Seastar. A number of actions identified require an extension/education effort to ensure effective implementation.

Actions

Prepare and distribute extension material to promote the uptake of the actions to be undertaken under this Plan and the importance of action to mitigate the environmental, economic and social impacts caused by Seastar as a key threatening process.

6. Administration

Objective 6: Effectively coordinate control activities

The activities and priorities under this Plan will need to ensure that field experience and research are applied to further improve management of the impacts of, and risks from, the Seastar on endangered and vulnerable species and the economic competitiveness of marine industries. Success will only be achieved if all key interest groups are involved in its further development and cooperate in its implementation.

The project will be managed overall by a NPS Control Advisory Group, which will consist of senior representatives from State/Territory conservation agencies, non-government conservation organisations, pest management experts and marine industry interests. The Group will meet at 6 monthly intervals to review progress, ensure full collaboration and data exchange, and make tactical adjustments to the project priorities and resource allocations. Key stakeholders will meet annually, to present results as they develop, discuss outcomes and implications, and provide input to the NPS Control Advisory Group on priority and task revisions. The activities and priorities under the Plan will need to evolve with, and adapt to, changes as they occur. As part of the annual review, the Plan's implementation will be subject to an independent audit to ensure the approach is the best possible and to strengthen confidence in the emerging results.

Actions

Establish a NPS Control Advisory Group with relevant technical and practical experience, convened by Environment Australia, to advise State and Commonwealth Ministers on implementation of the Plan.

Appoint a technical program manager, with expertise in managing marine pests, who will ensure optimal use of resources, effective scientific coordination, and quality assurance.

Convene annual meetings of key stakeholders to present incoming results, discuss outcomes and implications and provide input to the NPS Control Advisory Group.

Conduct annual review of the Plan's implementation, including an independent audit.

Commission a comprehensive review by an independent expert, of the progress made before the end of the five-year life of the Plan.

EVALUATION AND REVIEW

Effective management requires the Plan's evaluation. This helps ensure that the Plan and its implementation evolve by building on achievements and, where appropriate, modifying proposed approaches in the light of new knowledge.

Ultimately, the key performance indicator for the Plan is the degree of security achieved for areas and ecological processes of environmental and economic importance; including reduction in risks to threatened species and communities, and the economic competitiveness of marine industries. Assessment of this indicator will be made, as appropriate, during each review.

Evaluation and Review milestones

Task	Timing	Nature of resulting action
?? Technically evaluate and peer review projects in progress (NPS Control Advisory Group)	?? Years 1-5 (biannually)	?? Tactical adjustment to design of individual projects
?? Evaluate effectiveness of scope and direction of Plan	?? Years 1-5 (annually)	?? Strategic adjustment to the direction and timing of actions
?? Evaluate Plan and decide on long term options	?? Year 5	?? Decision on long-term control options

As specified in the actions relating to Objective 6, a NPS Control Advisory Group, will be established to monitor the implementation of the Plan. The team will include representatives from State/Territory agencies, non-government conservation organisations, pest management experts and marine industry interests. Environment Australia will provide a convenor and secretariat for the Group. The Group will monitor achievement of the performance criteria and milestones set out in the Plan and provide regular annual reports on progress. The annual meetings of key stakeholders will also provide input to this Group as outlined in the planned approach to objective 6.

Day-to-day management of the Plan will be provided by a senior scientist with expertise in the ecology and management of marine pests and in managing multi-disciplinary and multi-institutional research and development projects. The program manager will ensure effective use of resources and skills, coordination of effort and maintenance of the highest scientific and management standards for work undertaken in the Plan. The program manager will report to the NPS Control Advisory Group.

The Plan may be reviewed at any time if evidence is found that a control technique recommended in this Plan results in adverse impacts on a native species, including such that the species is becoming endangered, or that the approach to the Plan requires re-evaluation for other reasons.

At the end of the five-year life of the Plan an independent expert will be commissioned to examine the Plan and the supporting technical documents, and the success or otherwise of management actions undertaken. Recommendations from the review will then be used to establish long-term control options.

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