



An Australian Government Initiative

# NATIONAL CONTROL PLAN



European green shore crab  
*Carcinus maenas*



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



**Australian Government**

**National Control Plan  
for the European green shore crab  
*Carcinus maenas***

**Prepared for the Australian Government  
by Aquenal Pty Ltd**

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## BACKGROUND

The National System for the Prevention and Management of Marine Pest Incursions (the National System) has been developed to deal with the marine pest problem in Australia. Under the National System, introduced marine pests that are established in Australia that are having a significant impact and are not amenable to eradication will be addressed under the Ongoing Management and Control component. The key initiative under this component is the development and implementation of National Control Plans (NCPs), which reflect an agreed national response to reduce impacts and minimise spread of agreed pests of concern. The Australian, state and Northern Territory governments, through the National Introduced Marine Pests Coordination Group (NIMPCG), have determined that the following are agreed pests of concern, for which NCPs are required:

- Northern Pacific seastar (*Asterias amurensis*);
- European green crab (*Carcinus maenas*);
- Asian date mussel (*Musculista senhousia*);
- European fan worm (*Sabella spallanzanii*);
- Japanese seaweed (*Undaria pinnatifida*); and
- European clam (*Varicorbula gibba*).

The six NCPs for the above species are being developed in accordance with the Contents List that has been agreed by NIMPCG. The aims of the NCPs are to establish nationally agreed, species specific responses, secure their coordinated implementation across jurisdictions, and provide guidance on the development of future strategies to reduce impacts and minimise the spread of these pests.

This document outlines the NCP for the European green crab *Carcinus maenas*.

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## LIST OF ACRONYMS

CCIMPE	Consultative Committee on Introduced Marine Pest Emergencies
CPUE	Catch Per Unit Effort
CSIRO	Commonwealth Scientific and Research Organisation
DAFF	Department of Agriculture, Fisheries and Forestry
DEWHA	Department of the Environment, Water, Heritage and the Arts
EEOR	Emergency Eradication Operational Response
EMPPlan	Australian Emergency Marine Pest Plan
IMCRA	Interim Marine and Coastal Bioregionalisation for Australia
IMO	International Maritime Organisation
MPA	Marine Protected Area
NCPs	National Control Plans
NIMPCG	National Introduced Marine Pests Coordination Group
NIMPIS	National Introduced Marine Pest Information System
NMN	National Monitoring Network
R&D	Research and Development
RRM	Rapid Response Manual

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## A. *Vision statement and strategic overview*

### **Vision Statement:**

“To establish a nationally agreed response to *Carcinus maenas*, secure coordinated implementation across jurisdictions, and provide guidance on the development of future strategies to reduce impacts and minimise the spread of this pest.”

### **Strategic Overview:**

The National System for the Prevention and Management of Marine Pest Incursions (the National System) has been developed to deal with the marine pest problem in Australia. The objectives of the National System are to:

1. Prevent the introduction to Australia of exotic marine species;
2. Prevent the translocation within Australia of exotic marine species;
3. Provide emergency preparedness and response capacity to respond to and where feasible eradicate, outbreaks of exotic marine species; and
4. Manage and control exotic marine species where eradication is not feasible.

The National System has three major components:

1. Prevention: Prevention systems to reduce the risk of introduction and translocation of marine pests (including management arrangements for ballast water and biofouling);
2. Emergency Response: A coordinated emergency response to new incursions and translocations; and
3. Ongoing Management and Control: Managing introduced marine pests already in Australia.

The key initiative under the Ongoing Management and Control component of the National System is the development and implementation of National Control Plans (NCP's) for the following agreed pests of concern:

- Northern Pacific seastar (*Asterias amurensis*);
- European green crab (*Carcinus maenas*);
- Asian date mussel (*Musculista senhousia*);
- European fan worm (*Sabella spallanzanii*);
- Japanese seaweed (*Undaria pinnatifida*); and
- European clam (*Varicorbula gibba*).

Under the National System there is a process for identifying additional species for which development of NCPs may be required in the future. NCPs operate consistently with other elements of the National System, including ballast water management arrangements, biofouling guidelines, emergency management, communications and research and development. This document outlines the NCP for *Carcinus maenas* (hereafter referred to as *Carcinus*) and includes:

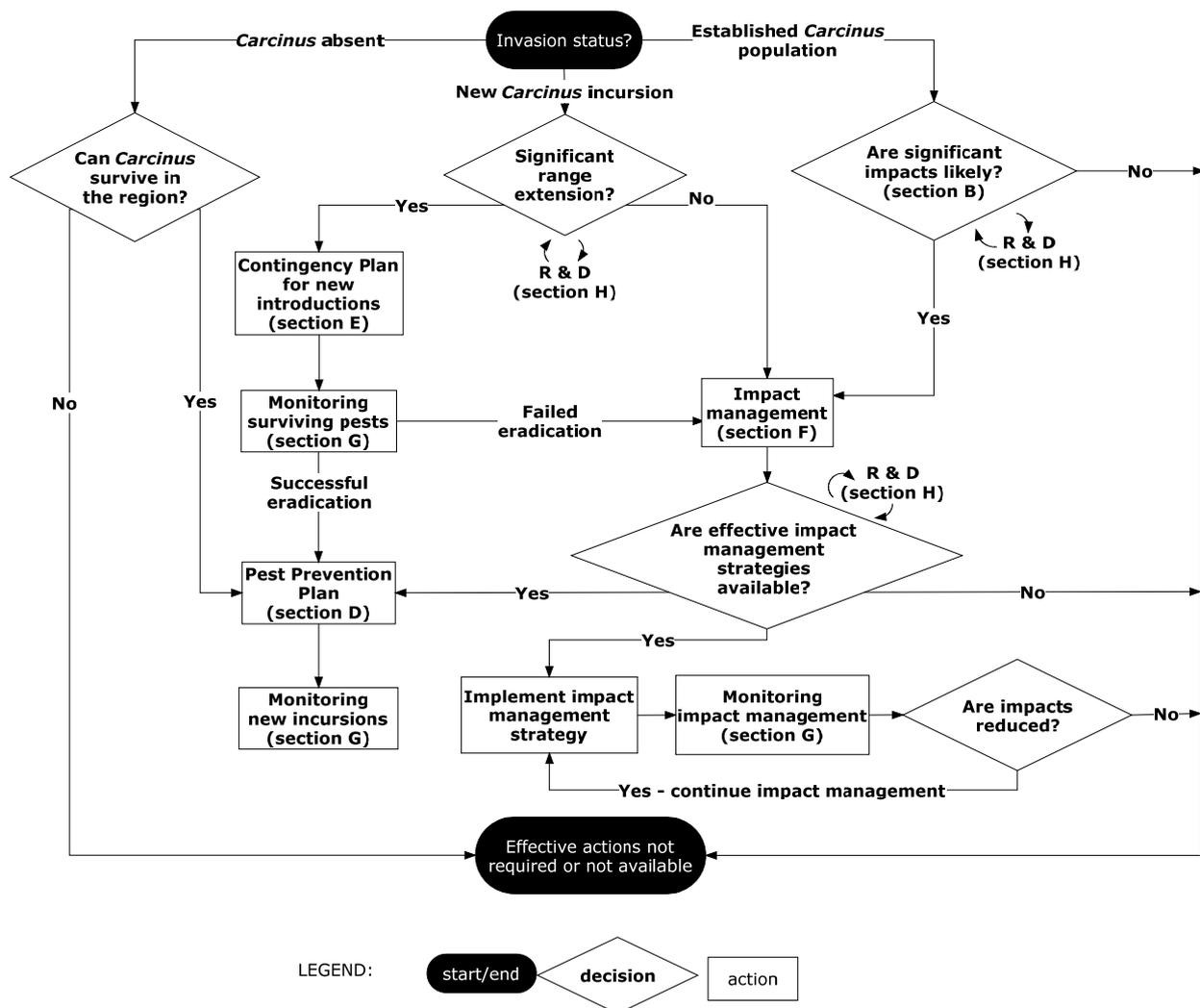
- practical management actions and cost effective approaches to improve any measures currently in place to prevent, control or manage the impacts of this species;

- contingency plans for new incursions, linking in with existing emergency arrangements, including those under development;
- creation of links with the National System monitoring strategy and recommendations for monitoring in addition to locations in the National Monitoring Network;
- recommendations for future research and development required to underpin the NCP;
- recommendations for public awareness and education strategies in addition to those planned under the National System; and
- estimated budgets and resource requirements to implement the NCP.

Decision support frameworks (in the form of flow charts and decision trees) have been included in relevant sections of the NCP. The decision support frameworks have been adapted and developed from a previous study that developed similar frameworks for marine pest management<sup>1</sup>. Four decision support frameworks have been developed including: (1) an overarching framework; (2) a pest prevention strategy; (3) a contingency plan for new introductions; and (4) an impact management framework. A monitoring decision support framework was not deemed necessary, since the need for additional monitoring is highlighted in each decision support framework. The decision support frameworks also provide the opportunity to highlight key R&D issues (discussed in detail in section H) which should improve the decision-making process. It should also be recognised that to be effective in the long-term the NCP should be viewed as a ‘living’ document that is reviewed and updated on a regular basis so that new information can be incorporated into the NCP. Development of new control technologies, for example, may influence the range of control options available to managers. Furthermore, management priorities may change with increasing knowledge of the spatial extent and impacts of *Carcinus* within Australian environments.

The overarching decision support framework for *Carcinus* management is shown in Figure 1. Managers should refer to individual sections of the NCP for further background information to assist the decision-making process.

It should be noted that the purpose of the NCP is to establish a nationally agreed management response to *Carcinus*, but it is not intended to represent a comprehensive field guide. In some circumstances managers will be required to refer to additional resources under the National System to implement particular sections of the NCP (e.g. biofouling guidelines, emergency response manuals). These additional resources are clearly outlined in the appropriate sections of the NCP and are provided as a list in Appendix I.



**Figure 1. Overarching decision support framework for *Carcinus* management.** There is inherent uncertainty associated with some questions (e.g. Can *Carcinus* survive in the region?) so decisions must be made on the best available information (e.g. Species range mapping data<sup>2</sup>). Note that if effective impact management strategies are available they will be integral to the “Impact management strategy”, but they may also be considered under the “Pest prevention plan” if effective reproductive output and spread can be reduced from source populations.

It is recognised that the number of pests and the likely impacts may vary substantially between jurisdictions so it will be essential to prioritise regional management activity. The purpose of the NCPs is to establish the ongoing control strategies that provide the best options for controlling the spread or impact of these species. It is beyond the scope of the NCPs to consider specific circumstances of each jurisdiction. Each jurisdiction needs to consider the costs and benefits of the proposed actions in relation to their specific circumstances and determine the ongoing control options that are most suitable for their jurisdiction. There are several tools available to assist managers to prioritise species for management purposes, such as the recommendations outlined in the Global Invasive Species Toolkit<sup>3</sup> (section 5.2 “Priorities for management”). As outlined in the Toolkit<sup>3</sup>, a number of criteria should be considered when prioritising pest species including: (1) current and potential extent of the species on or near the site; (2) current and potential impacts of the species; (3) value of the habitats/areas that the species infests or may infest; and (4) difficulty of control.

## B. Analysis of the level of threat posed by the species to national and regional environmental, social and economic values

This section of the NCP outlines the threat posed by *Carcinus* to environmental, social and economic values should the species not be controlled. It is based upon an assessment of demonstrable and potential impacts of *Carcinus* against the relevant CCIMPE criteria<sup>4</sup> (i.e. economy, environment, human health, amenity):

### **Economy:**

#### *Impacts in native and invaded ranges*

In its native range predation by *Carcinus* is considered a significant source of mortality for commercially important species, including blue mussels (*Mytilus edulis*<sup>5, 6</sup>), quahogs (*Mercenaria mercenaria*<sup>7</sup>), Pacific oysters (*Crassostrea gigas*<sup>8, 9</sup>), flat oysters (*Ostrea edulis*<sup>10</sup>) and clams (*Tapes decussatus*<sup>11</sup>).

Following invasion of North America, *Carcinus* has had substantial impacts on some commercially important clam species<sup>12</sup>, causing declines in production of up to 40 % in some years). On the east coast of North America, *Carcinus* has been associated with decline in populations of commercial shellfish species including soft shell clams (*Mya arenaria*<sup>13, 14</sup>) and scallops (*Argopecten irradians*<sup>15, 16</sup>). Potential economic losses associated with *Carcinus* invasion in North America have been estimated to be as high as \$AUD 49M per year<sup>17</sup>, although the magnitude of these impacts has recently come into question<sup>18</sup>. It should also be noted that much of the evidence supporting economic impacts of *Carcinus* is correlative and that alternative explanations for the decline of commercial shellfish populations (e.g. overfishing, climate change) have not been explored<sup>19</sup>.

#### *Impacts in Australia*

There is currently no documented evidence of direct impacts of *Carcinus* on mariculture or fisheries within Australia (refer to NIMPIS<sup>20</sup> for details on *Carcinus* range). *Carcinus* has the potential to impact aquaculture operations, particularly those involving culture of bivalve molluscs, an industry estimated to be valued at > \$AUD 84M per year<sup>21</sup>. At this stage it appears that the impact is minor, although there are anecdotal reports of losses of juvenile oysters in some regions<sup>22</sup> (A. Morton, Tasmanian Department of Primary Industries and Water, pers. comm., October 2007). Oyster farmers on the east coast of Tasmania have experienced substantial losses of juveniles (ascribable to *Carcinus* predation) in some years leading some operators to change their aquaculture practices (C. Dyke, Oyster Bay Oysters, pers. comm., November 2007). Growing juvenile oysters in sealed baskets (rather than previously used open baskets) prevents predation impacts caused by *Carcinus* (C. Dyke, pers. comm.). The costs associated with these changes are estimated to be \$AUD50K for a farm producing approx 1.2M oysters annually (C. Dyke, pers. comm.).

It has been suggested that the lack of major economic impacts caused by *Carcinus* in Australia is due to the fact that the main aquaculture species (oysters, mussels) are farmed in cages/lines that are suspended above the bottom<sup>23</sup>. Aquaculture operations that involve growing animals directly on the seabed (e.g. scallop farming in Norway<sup>24</sup>) would be exposed to a high level of risk of *Carcinus* predation impacts, however such practices are not currently used in Australia.

The presence of *Carcinus* has the potential to impact clam and cockle fisheries, such as those targeting *Katelysia* sp. and *Venerupis* sp. in sheltered bays on the east coast of Tasmania. These relatively small-scale fisheries are of minor economic importance (combined average beach value of

\$AUD 234K per year, based on average earnings 2001-2005<sup>25</sup>), but their long-term viability may be affected by the presence of *Carcinus*. Surveys and experimental manipulations have demonstrated clear evidence of impacts of *Carcinus* on *Katelysia* populations, including depressed survival to adulthood in areas where the crab is present<sup>26</sup>. Other cockle fisheries (e.g. Goolwa cockle *Donax deltoides*) that harvest animals from high energy surf zones are not likely to be affected by *Carcinus*, due to its preference for low energy, sheltered habitat conditions.

It has also been speculated that *Carcinus* has the potential to influence production of scallop fisheries (value \$AUD 25M per year<sup>21</sup>), however this interaction is considered unlikely based upon differences in preferred environmental conditions between the species. For example, in Tasmania the preferred depth of *Carcinus* (shallow subtidal, 3 m) is shallower than the preferred habitat of the main commercial scallop species (*Pecten fumatus*) which is found in much deeper water<sup>23</sup>. If crabs are capable of seasonal movement into deeper water, there may be impacts on the fishery<sup>23</sup>, but this interaction is considered unlikely considering the fact that the scallop fishery is based largely on the open coast and *Carcinus* is typically restricted to sheltered bays and inlets.

### **Environment:**

#### *Impacts in native and invaded ranges*

Significant impacts of *Carcinus* have been demonstrated in both the native range and introduced regions<sup>11</sup>. Predation effects due to *Carcinus* have the potential to influence the abundance and distribution of a range of marine taxa, particularly bivalve molluscs, polychaetes, and small crustaceans<sup>11</sup>. On the west coast of North America, for example, significant declines in native clam and shorecrab species are attributed to *Carcinus* invasion<sup>27</sup>. Indirect impacts on benthic communities (e.g. increases in polychaetes and tube building crustaceans) caused by removal of *Carcinus* prey, have also been observed following *Carcinus* invasion<sup>27</sup>. Current evidence suggests that impacts are restricted to lower trophic levels, since there have been no demonstrated impacts on higher trophic levels (e.g. shorebirds<sup>27</sup>). Predation impacts caused by *Carcinus* have also induced measurable changes in the morphology of intertidal snails on the east coast of North America<sup>28-31</sup>.

While many of these studies demonstrate impacts of *Carcinus*, there are also recent examples that show that native predators can confer resistance ('biotic resistance') to invasion by *Carcinus*<sup>32, 33</sup>. Detailed examination of the environmental and biological parameters that limit *Carcinus* invasion in west coast embayments in North America showed that adult *Carcinus* were in fact very spatially limited, occurring primarily in warm, shallow areas that lacked large native crabs (*Cancer* spp.). These results suggest that the potential distribution of *Carcinus* on the west coast of North America will be far less than previously predicted, and that their impacts may be largely attenuated through predation and competition with native crab species<sup>33</sup>.

#### *Impacts in Australia*

In Australia, impact studies are restricted to a limited number of studies carried out in Tasmania<sup>26, 34-37</sup> which in some cases demonstrate significant negative impacts on native bivalve and crab populations in soft sediment habitats. While impact studies have not been conducted on mainland Australia, *Carcinus* does not reach high densities as in Tasmania and is not perceived to have a large impact<sup>38</sup>. The reasons underlying these apparent differences remain unknown, however, it has been speculated that native crab populations on the mainland may control *Carcinus* populations. For example, the blue swimmer crab (*Portunus pelagicus*) is present on the mainland and it has been suggested that this large aggressive crab may be competitively dominant over *Carcinus*<sup>38</sup>. It should

be emphasised, however, that perceived impacts on the Australian mainland must be treated with caution in the absence of experimental data.

**Human health & Amenity:**

There are no reported or anticipated human health concerns associated with *Carcinus* populations in either the native or invaded range. Impacts on amenity are likely to be minor, although loss of harvest for recreational fishers (e.g. cockles) may be significant in some regions.

*C. The business case that led to the decision to establish a National Control Plan for the species*

The business case that led to the decision to establish a NCP for *Carcinus* was finalised in 2006<sup>39</sup>. The business case summarises the likely threat and impacts of *Carcinus* and provides an outline of the likely benefits and costs of implementing the NCPs.

**Business case**

NIMPCG considers that there is a business case for the development and implementation of a NCP for *Carcinus*, given that implementation of the NCP will provide significantly improved coordination and management through nationally agreed responses.

The key information that informed NIMPCG is below:

*Actual and potential impacts of Carcinus*

*Carcinus* has been assessed by NIMPCG as having significant current and potential future impacts on Australia's marine environment, social uses of the marine environment and the economy. A summary of impacts known from existing infestations, which will occur at new sites if they are invaded, is as follows:

*Carcinus* is a voracious predator on native species and commercially farmed shellfish causing loss of aquaculture, recreational and commercial harvest. It dominates, out-competes, and preys on native species. It is present in 10 out of 60 Australian marine bioregions (as defined in the Interim Marine and Coastal Bioregionalisation for Australia – IMCRA<sup>40</sup>).

*Potential for further introductions and spread of Carcinus*

*Carcinus* can be transported in ballast water and via biofouling.

CSIRO has assessed the invasion potential of 53 introduced marine species, on the basis of: ballast water volumes discharged into Australian and ports, the hull surface area of vessels that enter ports (which increases biofouling potential). *Carcinus* has significant potential to invade additional places in IMCRA bioregions where the species are already present, as well as bioregions which have not yet been invaded.

*Carcinus* has the potential to survive and complete its life cycle at places with suitable water depths along the southern Australian coast for at least some part of the year. Many other environmental factors affect the ability of *Carcinus* to establish pest populations. However on the basis of water temperature it has the potential to invade 28 bioregions (currently present in 10).

*Benefits of National Control Plans*

NIMPCG considers that the implementation of a NCP for *Carcinus* and the associated implementation of ballast water controls, inclusion of the species on the trigger species list under the Emergency management element, and inclusion as a target species for the National Monitoring Network will substantially reduce its spread in the short term.

In the long-term a research and development program for *Carcinus* designed to address the strategic needs of the NCP has the potential to provide more effective vector controls and means of addressing existing populations.

*Costs of National Control Plans*

<b>Control measure</b>	<b>National System Component</b>	<b>Annual Cost</b>
Operation of Ballast Water Framework	Prevention	\$2.91 m
Ballast Water Exchanges and delays to shipping	Prevention	\$6.99 m
National Monitoring network	Supporting arrangements	\$0.96 m
Emergency management arrangements	Emergency management	\$0.17m
Emergency responses - cost shared	Emergency management	Case-by case
Research and development	Supporting arrangements	Case-by case
Total (six species)		[At least] \$10.96m

*Cost - Benefit Analysis*

Cost Benefit analysis for the implementation of NCPs cannot be precise as the losses to production values and the marine environment that would occur in the absence of control measures cannot be estimated. However consultants have estimated that, taking into account only the potential benefits to fisheries and aquaculture at only three sites where each of the species may have impacts, the benefit to cost ratio for a NCP for the six species ranges between 0 and 2.8. For *Carcinus*, the benefit to cost ratio was 1.3 where eradication of the species was not considered possible and 0.4 where eradication of some incursions was considered possible. When the potential benefits for the marine environment are included, these ratios of benefits to cost will be exceeded.

**Consultation**

Consultation on the objectives and measures to be contained in NCPs and the business case for the initial six NCPs was conducted through NIMPCG.

D. A Pest Prevention Plan, which will refer to:

-national System ballast water management arrangements, where relevant to the species;

-national System best practice guidelines for management of biofouling; and

-any other prevention strategies that are targeted specifically at the species or should be considered for the future.

**Ballast water:**

A generalised pest prevention framework that outlines the range of pest prevention strategies applicable to *Carcinus*, including existing arrangements, is shown in Figure 2. Reducing the risk of ballast water – mediated translocation of *Carcinus* within Australia will be addressed by new ballast water arrangements currently under development. NIMPCG has agreed that ships carrying high risk ballast water on domestic voyages may be required to exchange ballast water at least 12 nm from the Australian coast (with the exception of the Great Barrier Reef and Torres Strait which are still under consideration). It is expected that ballast water exchange in the Australian domestic ballast water arrangements will be consistent with International Maritime Organisation (IMO) regulations. This involves at least 95 % volumetric exchange conducted in water at least 200 m deep. The legislation for the Australian domestic ballast water arrangements is currently in the process of being developed and it is expected to come into affect by July 2009. *Carcinus* has been nominated as one of the species for which ballast water management between Australian ports will be required.

While the new ballast water arrangements should reduce the risk of *Carcinus* translocation, it must be recognised that it may not be sufficient to prevent spread of larvae, because *Carcinus* has a long larval period (upwards of 36-50 days<sup>41, 42</sup>). Natural dispersal of *Carcinus* larvae involves transport offshore (up to 37 km) before returning to coastal regions for settlement<sup>43-45</sup>. Consequently, while exchange should reduce the risk of translocation, it should be recognised that if *Carcinus* larvae are entrained in ballast water, discharge of the ballast water close to the 12 nm limit could result in translocation to a new region given favourable currents.

**Biofouling:**

*Carcinus* can also be transferred via biofouling. National best practice management guidelines for management of biofouling are currently being developed for various marine sectors<sup>46</sup> including domestic recreational vessels, aquaculture, commercial fishing and petroleum industries. *Carcinus* translocation via biofouling on vessel hulls should only be an issue for highly fouled vessels because mobile species such as *Carcinus* are only likely to be present on heavily fouled hulls (A. Coutts, Australian Quarantine and Inspection Service, pers. comm., October 2007). Adherence to these guidelines should ensure that translocation risk is reduced.

Translocation of *Carcinus* in association with aquaculture activities is also being addressed through guidelines that are currently under development. The aquaculture sector is of particular relevance to translocation of *Carcinus*, because previous translocations have been linked to aquaculture activities in North America<sup>19</sup>. One possible explanation for this pattern is inadvertent transfer of juvenile *Carcinus* associated with transfer of aquaculture shellfish stock<sup>19</sup>. Other possible reasons are

enhanced survival or aggregations in areas of increased food availability<sup>47</sup> or enhanced detection of *Carcinus* due to the familiarity of aquaculturists with local fauna<sup>19</sup>.

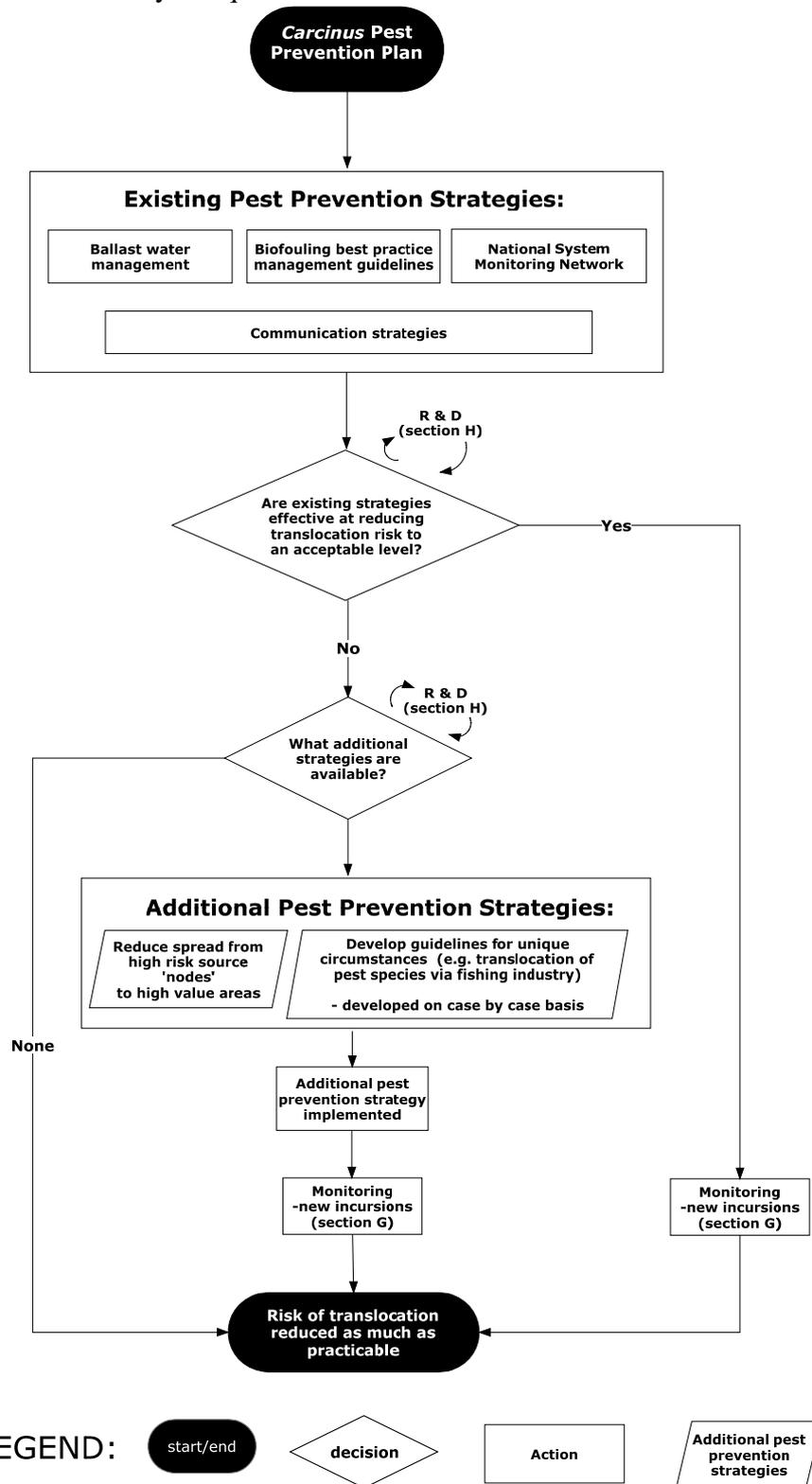


Figure 2. Pest prevention plan and decision support framework applicable to *Carcinus*.

**Additional Pest Prevention Strategies:**

- Transfer of *Carcinus* from high risk nodes (e.g. infested ports, marinas) to high value areas (e.g. MPAs, important aquaculture regions) may also warrant additional pest prevention measures. For example, sterilisation of hull and internal seawater systems might be recommended for vessels travelling to high value areas. Effective public awareness and communication campaigns will be an integral component of this strategy.
- Other pest prevention strategies may arise on a case-by-case basis. A good example of an additional pest prevention strategy is the recent development of protocols designed to prevent translocation of *Asterias amurensis* by scallop fishers on the east coast of Tasmania<sup>48</sup>. Fishers have been provided with a clear set of guidelines that outline cleaning procedures to prevent translocation between fishing grounds, along with clear instructions on how to store *A. amurensis* that have been caught in their fishing gear (e.g. non-draining bins). Similar protocols may need to be developed if there is risk of *Carcinus* entrainment and translocation associated with fishing or related activities.

*E. A contingency plan for responses to new introductions and translocations, including reference to National System emergency management arrangements*

A framework for responding to new introductions and translocations of *Carcinus* is provided in Figure 3. The decision on a national response to eradicate new introductions or range extensions of *Carcinus* is dependent on whether or not a ‘significant range extension’ has occurred. As defined in the CCIMPE Standard Operating Guidelines<sup>4</sup>, a significant range extension is considered to have occurred when the secondary introduction of an exotic marine pest species, that is limited in its known distribution within Australia, is detected that is deemed:

1. *to meet the EMPPlan criteria for a marine pest emergency alert;*
  2. *is unlikely to be due to spread by natural means;*
- and either:**
- 3(a). *is likely to have considerable direct impacts on the economy, environment, public health, and/or amenity in the affected region;*
- or**
- 3(b). *is likely to considerably increase the indirect risk to assets (economic, environmental, public health, and/or amenity) in other regions.*

If a significant range extension has occurred and it is deemed feasible to eradicate the new incursion, an Emergency Eradication Operational Response (EEOR) may be instigated, pending approval of the National Management Group. A detailed breakdown of the EEOR and the procedures to be followed in the case of a marine pest emergency can be found in the Australian Emergency Marine Pest Plan (EMPPlan)<sup>49</sup>.

A key component of the EEOR involves implementation of measures to eradicate the pest species from infested sites. Rapid Response Manuals (RRMs) are currently under development (commissioned by the Australian Government Department of Agriculture Fisheries and Forestry (DAFF)) that will specifically deal with eradication options for new *Carcinus* incursions. The National Introduced Marine Pest Information System (NIMPIS) rapid response toolbox<sup>50</sup> also provides a range of physical, chemical and biological eradication options that should be consulted in the case of a marine pest emergency, while a recent review of currently available technology commissioned by DAFF provides an up-to-date assessment of emergency eradication options including novel treatment methods<sup>51</sup>. Another recently commissioned DAFF study provides tools to estimate the cost involved in emergency eradication or response based on the biology of the pest species and environmental conditions of the infected site<sup>52</sup>.

The range of treatment options available for a marine pest emergency involving *Carcinus* depends on the area of infestation and the environmental circumstances associated with the incursion. As applies to all marine pest emergencies, the most effective way to deal with a new *Carcinus* incursion is to detect it early and eradicate or contain the population before further spread occurs.

A key question for managers when responding to new *Carcinus* translocations is whether or not the introduction is deemed “unlikely to be due to spread by natural means”. This necessitates an understanding of the capacity for natural spread, which depends on the interaction between larval life history and local environment<sup>53</sup>. Given the long larval period of *Carcinus* (upwards of 36-50 days<sup>41, 42</sup>), it is likely that long distance spread via natural dispersal could occur, however this has

not been tested because of the practical limitations associated with tagging and tracking larvae<sup>19</sup>. In North America, range extensions up to 200 km per year have been observed, however it remains unclear whether human mediated vectors have contributed to these patterns of spread<sup>19</sup>.

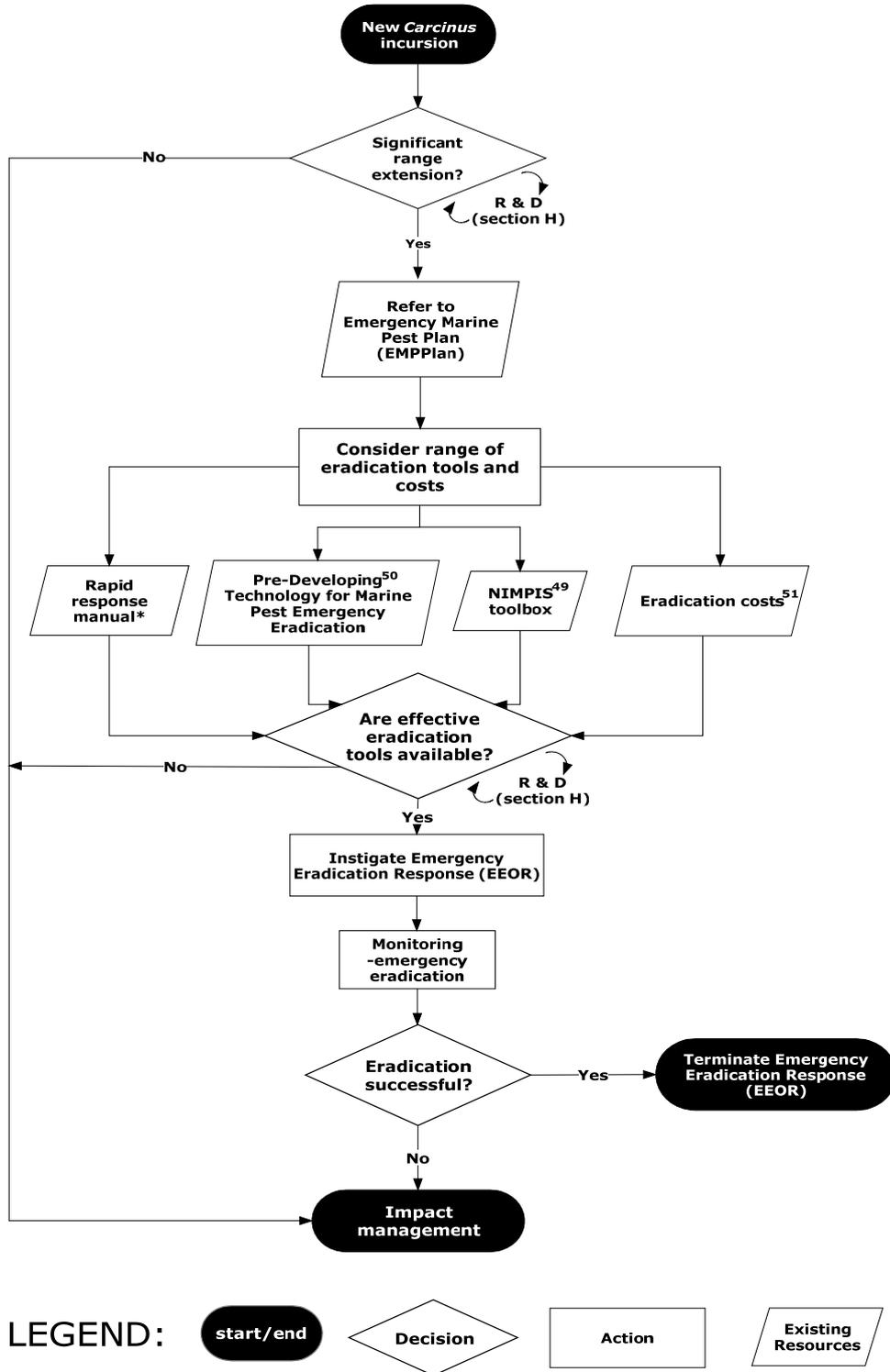


Figure 3. Decision support framework for new introductions of *Carcinus* highlighting the currently available resources to assist the decision-making process. \*Resources currently under development.

*F. A plan for species impact management i.e. physical, chemical and biological measures to attack existing populations if feasible; and habitat management*

A generalised decision support framework applicable for *Carcinus* impact management is outlined in Figure 4. Assessing impacts is the first stage in the decision-making process which will be based on likely impacts for most jurisdictions given the current lack of impact data in Australian environments (see section B). It is not appropriate to assign *Carcinus* to impact categories across all jurisdictions since the extent of impacts will depend upon the industries operating within a jurisdiction, the nature of biological communities and habitats present, and other values of the region. Prioritisation for management purposes will also be based on relative impacts and the presence of other pest species within a particular jurisdiction. Notwithstanding these issues, in most jurisdictions *Carcinus* impact is likely to be in the ‘low-moderate’ categories for economic impact and the ‘moderate’ category for environmental impact based on the analysis of impacts detailed in section B.

Before potential impact management options are identified, it is important to establish clear objectives for management which can be used to measure the subsequent success of management actions. As part of the decision-making process it is also vital to assess the likely benefits of impact management and the costs involved in implementing the impact management strategy. To justify investment in on-going control, it is essential that likely benefits exceed management costs. In most circumstances it will not be possible to control all populations, so it will be at the discretion of each jurisdiction to identify high value areas (e.g. MPAs, fisheries, key aquaculture areas) where there is greatest need to reduce impact. In relation to determining environmental values, resources such as ‘The Interim Marine and Coastal Regionalisation of Australia (IMCRA)<sup>40</sup>’ should be consulted to identify areas of biological significance.

**Currently available impact management options:**

Impact management options are defined under three broad categories, including (1) direct targeting of *Carcinus*; (2) habitat management and (3) impact mitigation. A summary of the efficacy and feasibility of currently available options is provided in Table 1. It should be recognised that the various impact management options are not mutually exclusive and multiple methodologies may be incorporated into an integrated management strategy. The range of available impact management options will largely depend on the management objectives. The likely effectiveness and feasibility of impact management will also depend on the spatial extent and density of the target population which will require assessment on a case-by-case basis.

*(1) Direct targeting of Carcinus:*

Physical removal

Of the currently available impact management options, trapping is considered the most effective for reducing *Carcinus* population size. The main benefit of trapping is that large numbers of *Carcinus* can be easily removed with no associated environmental concerns, such as those associated with the use of poison baits (see below). The efficacy of trapping is questionable, however, when crabs are present in high densities because significant numbers may be removed with negligible effects on overall population numbers and impact<sup>54</sup>.

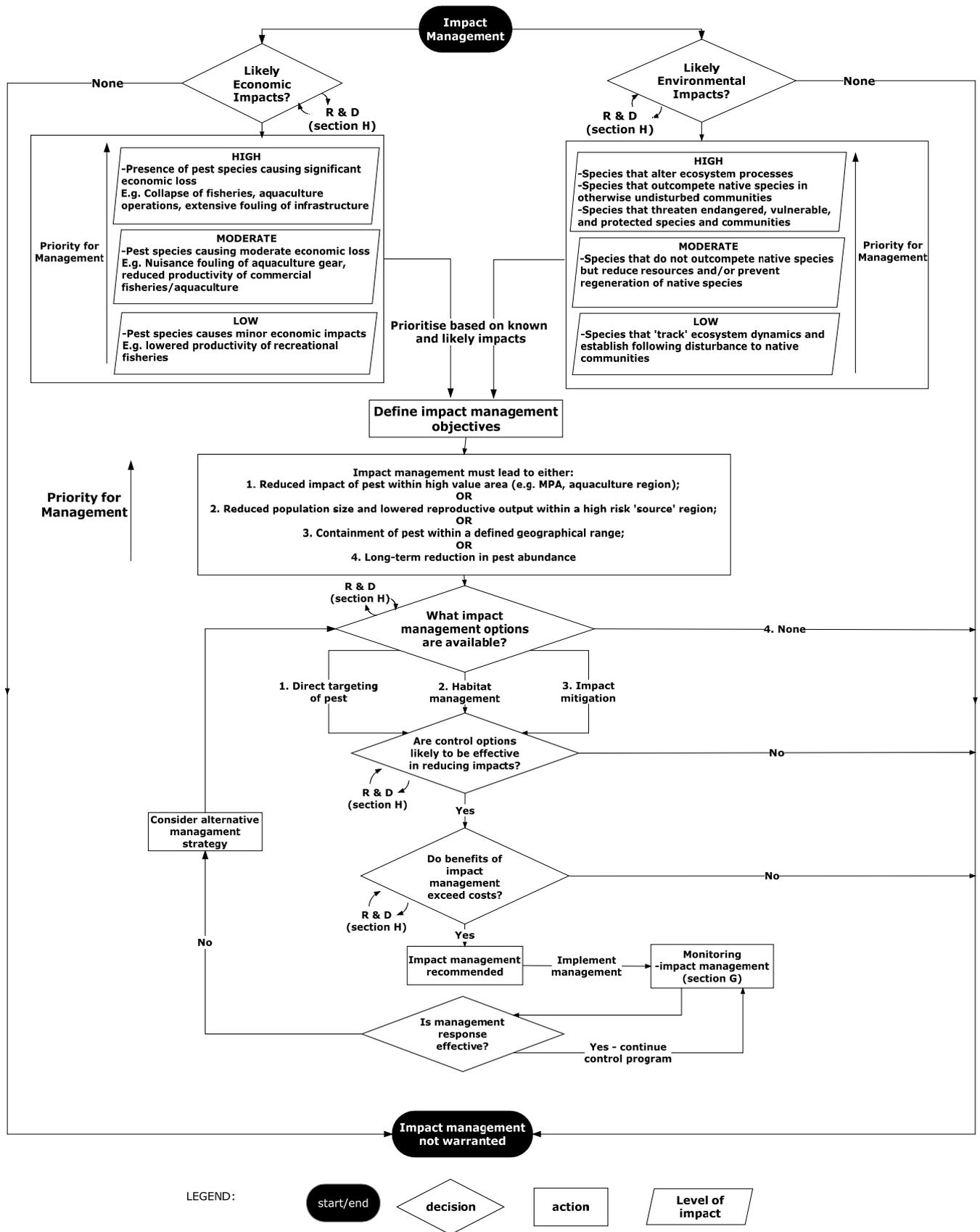


Figure 4. Impact management decision support framework applicable to *Carcinus*.

Unfortunately there is little in the way of empirical evidence demonstrating the effectiveness of trapping to reduce population size. Trapping of *Carcinus* in the vicinity of Martha's vineyard on the east coast of North America has not resulted in decline of *Carcinus* populations, despite considerable effort<sup>55</sup>. A bounty system in the same region has also proved largely ineffective in reducing *Carcinus* populations<sup>11</sup>. While control of *Carcinus* populations on a large scale have not been successful, trapping in small embayments can reduce *Carcinus* density and deserves consideration as an impact management strategy, because they represent relatively closed systems which may be vulnerable to reduction in crab abundance given appropriate harvest levels<sup>55</sup>.

A recently initiated *Carcinus* trapping program in Bodega Bay Harbour, a small embayment (approximately 4.5 km<sup>2</sup>) on the east coast of North America, provides a good example of successful control of a *Carcinus* population. While the program is on-going, 9691 crabs have been removed over 66 trapping days, with CPUE declining from 21.3 crabs per trap in July 2006 to 1.4 crabs per trap in December 2006<sup>56</sup>. Concurrent mark-recapture studies indicate that the population has declined significantly. A similar trapping program initiated in February 2007 by the Sapphire Bay Marine Discovery Centre focuses on a small estuary (0.05 km<sup>2</sup>) near Eden on the South Coast of New South Wales. Preliminary results suggests that the trapping program has been successful in reducing *Carcinus* density with the number of animals caught in early trapping sessions exceeding 200 animals per night, while only 3 animals were captured in the most recent trapping session (A. Broadhurst, Sapphire Bay Marine Discovery Centre, pers. comm., December 2007). The Sapphire Bay Marine Discovery Centre is hoping to extend their trapping program to include different trap designs to test their efficacy against smaller *Carcinus* individual that are not captured in conventional crab traps.

There are two important commonalities contributing to the apparent success of these trapping programs. Firstly, both bays are relatively small, isolated systems. Secondly, for both of these programs trapping has been largely carried out by volunteers, representing a significant cost saving (see Budget, section K).

A number of factors require consideration before undertaking a *Carcinus* trapping program. In relation to trap design, a range of standard traps have been successful in capturing *Carcinus* including minnow traps<sup>57</sup>, conventional box traps<sup>58</sup> and opera house traps (A. Broadhurst, pers. comm.). Fresh fish baits (e.g. mackerel) have proven most effective for *Carcinus*, though other successful baits include salmon, calamari, oysters, razor clams, mussels and cat food<sup>59</sup>. Local baits should also be used to minimise the risk of disease translocation. Seasonal variation in water temperature and its effects on *Carcinus* catch rates may also require consideration. In North America, higher catch rates of *Carcinus* have been correlated with increased warm water temperature over the summer period<sup>57</sup> and similar patterns have been observed in Tasmania<sup>58</sup>. Seasonal movement of *Carcinus* has also been observed elsewhere<sup>60</sup> and has the potential to influence trapping success, however this remain untested in Australian environments. Similarly, it remains unknown whether the reproductive status of *Carcinus* influences trapping success, as observed in other crab species<sup>61</sup>. For more detailed discussion of the effectiveness of trapping as a control measure against mobile crustaceans refer to the recent review "Pre-Developing Technology for Marine Pest Emergency Eradication Response: Review of Current Technology"<sup>51</sup>.

#### Biological control

Biological control has been considered previously as a control option for *Carcinus*<sup>62</sup> and the parasitic castrator *Sacculina carcini* has been the subject of experimental trials<sup>63, 64</sup>. While effective against *Carcinus*, *S. carcini* also infected native crabs and further research is required on host specificity, efficacy and infection rates<sup>54</sup>. Genetic manipulation of pest species is the subject of ongoing research

efforts at CSIRO. Modelling studies show that it could be an effective control strategy to reduce or eradicate pest populations<sup>65</sup>. While the technique has great potential (e.g. sonless/daughterless offspring), public concern and legislative restrictions associated with release of genetically manipulated organisms would need to be overcome before it could be applied in a field setting in the marine environment.

#### Chemical control

Poison baits (baits soaked in the organocarbamate pesticide 'Carbaryl') have been previously considered as a potential control option for mobile crustaceans such as *Carcinus*<sup>66</sup>. The major advantage of poisoned baits is that they are not size selective like trapping methods. 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'<sup>67</sup>. The main limitation of this method relates to suitable chemicals for poison baits and the possibility for chemicals to leach from baits into the surrounding environment. Although carbaryl is relatively short-lived in the marine environment and does not bioaccumulate in the food chain, it is likely to have a significant impact on non-target species. There are also significant issues associated with handling carbaryl that must be considered in any control strategy. For example, a recent review in Australia by the Australian Pesticides and Veterinary Medicines Authority has recommended tighter restrictions on the domestic and commercial use of carbaryl due to toxicological risks<sup>68</sup>. Consequently, if permission to use carbaryl was granted, a rigorous public awareness campaign would be essential in areas where poison baits are deployed.

#### (2) *Habitat management:*

On the east coast of North America biotic resistance provided by native crab populations has been demonstrated to be the underlying cause of the restricted spatial extent of *Carcinus* populations<sup>32</sup>. It has been suggested that biotic resistance provided by native predators could be compromised in circumstances where native predators are targeted for commercial purposes (i.e. fishing)<sup>33</sup>. Therefore managing predator populations represents a potential habitat management option for control of *Carcinus*. In an Australian context this approach holds promise as a management tool, since it has been suggested that native crabs may be competitively dominant over *Carcinus*<sup>38</sup>. However, significant research efforts are required in Australian environments before it can be considered a serious management option.

#### (3) *Impact mitigation:*

Impact mitigation is a potentially promising management strategy against the impacts of *Carcinus*, particularly in relation to shellfish aquaculture. Impact mitigation may involve engineering solutions (e.g. different design of spat bags, cages, racks) or it may involve modifying aquaculture or fisheries practices to minimise interactions between *Carcinus* and the particular commercial species of interest. For example, in North America *Carcinus* are significant predators of juvenile shellfish 'seedstock' that are outplanted to enhance wild populations (e.g. *Venerupis philippinarum*, *Mercenaria mercenaria*). Consequently, a range of impact mitigation strategies have been evaluated to reduce predation impacts including timing of outplanting and the size and density of seedstock<sup>12, 69</sup>. Barriers (fences) are used in Norway to minimise interaction between scallops farmed on the seabed and a predatory crab (*Cancer pagurus*)<sup>24</sup>. It remains unknown whether such barriers would be effective against *Carcinus*.

Juvenile oysters are vulnerable to predation by *Carcinus* and in some years significant loss of stock has occurred in Tasmania (C. Dyke, pers. comm.) and NSW<sup>22</sup>. To reduce these impacts, oyster farmers in Tasmania now grow juvenile oysters in sealed baskets (rather than open baskets used previously) to prevent predation by *Carcinus*. With this minor change in operations, the impacts of *Carcinus* are now

considered negligible (C. Dyke, pers. comm.). At present the impacts of *Carcinus* on aquaculture operations in Australia are generally considered relatively low so there has been little incentive to develop this type of impact mitigation strategy. Should impacts increase in the future an impact mitigation strategy will be central to minimising economic loss caused by *Carcinus*. It is likely that aquaculture operations that utilise the seabed directly would be most susceptible to *Carcinus* related impacts.

**Carcinus invasion biology and implications for impact management:**

Past research examining the invasion biology of *Carcinus* in Australia, South Africa and the east coast of North America has significant implications for control and the range of management objectives that should be considered achievable<sup>19</sup>. Despite the potential for long distance dispersal by *Carcinus* larvae, the pattern of invasion by *Carcinus* consists of periods of relative stasis punctuated by rare long distance dispersal events<sup>19</sup>. For example, colonisation of Tasmania from Victoria took more than 100 years despite suitable ocean currents and apparently suitable environmental conditions. Furthermore, following the initial invasion of the Tasmanian coastline in the early 1990s, there was little or no further range expansion over the next ten years<sup>19</sup>. The reasons underlying these pattern remain unclear, although unfavourable ocean currents and locally intense predation have been suggested as potential causes.

These patterns of invasion have three significant implications in relation to impact management and the range of management objectives that should be considered feasible:

1. The common perception that local eradication is fruitless because local currents will rapidly spread larvae from adjacent source populations<sup>70</sup> may not be generally applicable to *Carcinus* since connectivity between populations in adjacent Bays is likely to be very low.
2. Management efforts to contain *Carcinus* populations within a defined geographical range should be considered but episodic large scale recruitment events are beyond the scope of management.
3. Controlling populations within high risk source regions to minimise further spread via larval dispersal is not likely to be an effective control option, since there is no evidence that established populations have acted as nodes for expansion ‘down-current’ from established populations<sup>19</sup>. High risk source populations should only be targeted if the source population is potentially related to ‘human-mediated’ spread (e.g. ballast water, aquaculture activities).

**Table 1. Currently available impact management options for *Carcinus*. (Note that potential control options such as genetic control that are under development are not included in the table).**

<b>Method</b>	<b>Likely Efficacy</b>	<b>Feasibility</b>	<b>Environmental/public concerns</b>
<b>1. Directly targeting <i>Carcinus</i></b> <i>-Trapping</i>  <i>-Poison baits</i> (e.g. <i>Carbaryl laced baits</i> )	<p>May be effective in reducing adult population density.</p> <p>May be effective in reducing density. Has the advantage over trapping because the method is not size selective.</p>	<p>Feasible on small-moderate spatial scale*. If abundance high, unlikely to reduce impacts due to high fecundity and impacts caused by juveniles.</p> <p>Feasible on small-moderate spatial scale*.</p>	<p>Minimal environmental concerns. By-catch release unharmed.</p> <p>Concerns associated with chemicals leaching from baits and effects on non-target biota.</p>
<b>2. Habitat management</b> <i>-Maintain integrity of native predator populations</i>  <i>-Enhancement of native predators</i>	<p>May reduce population density and/or provide resistance to further invasion ('biotic resistance').</p> <p>May reduce <i>Carcinus</i> population density.</p>	<p>Potentially effective if abundance of predators influenced by human activity (e.g. fishing, habitat degradation). Some regions may not have significant <i>Carcinus</i> predators.</p> <p>Probably only effective on a small spatial scale*. Potential <i>Carcinus</i> predators in Australia poorly known.</p>	<p>May need stricter control on fishing of predators (e.g. fishing regulations), leading to public dissatisfaction.</p> <p>Native predators may need to be sourced from elsewhere.</p>
<b>3. Impact Mitigation</b> <i>-Engineering solutions</i> (e.g. modification of aquaculture equipment to minimise interaction between <i>Carcinus</i> and aquaculture species).  <i>-Modify aquaculture practices</i> (e.g. place animals in areas where <i>Carcinus</i> density low and/or introduce juveniles when <i>Carcinus</i> activity low).  <i>-Barriers for aquaculture</i>	<p>May be effective in reducing impacts if <i>Carcinus</i> can be effectively excluded from aquaculture equipment.</p> <p>May be effective. Effectiveness could be compromised if <i>Carcinus</i> attracted to aquaculture infrastructure.</p> <p>Potentially effective method to exclude adult <i>Carcinus</i> from aquaculture areas.</p>	<p>Changes to aquaculture design may lead to loss of productivity.</p> <p>Requires understanding of the spatial distribution of <i>Carcinus</i> populations.</p> <p>Only likely to be feasible on small spatial scales. Would require significant investment to build and maintain barriers.</p>	<p>Minimal environmental concerns.</p> <p>Minimal environmental concerns.</p> <p>Minimal environmental concerns.</p>

\*Small spatial scale = < 1000 m<sup>2</sup>; moderate spatial scale = 1000 – 10 000 m<sup>2</sup>; large spatial scale = > 10 000 m<sup>2</sup>.

**Overall recommendations:**

- If practical, impact management strategies should focus on reducing *Carcinus* abundance and/or impact mitigation in high value areas (e.g. aquaculture regions, MPAs, regions where threatened species or communities are present).
- Control of *Carcinus* in high risk source regions should only be considered if the risk is associated with human mediated transport (e.g. ballast water, aquaculture activities).
- Long-term reduction in pest abundance should be considered as a realistic management objective in areas that are not necessarily considered ‘high value’, but where the chances of impact reduction are high. For example, in small bays and inlets, long-term reduction (or even eradication) of *Carcinus* populations may be achievable with relatively little effort.

### *G. A monitoring strategy for the species, including the National System Monitoring Network and Monitoring Guidelines*

Monitoring of *Carcinus* is included in the National Monitoring Network (NMN), which is comprised of 18 locations across Australia<sup>71</sup>. Guidelines for monitoring *Carcinus* within the NMN are included in the Marine Pest Monitoring Manual<sup>72</sup>. The primary objectives of the network are: (1) to detect new incursions of established target species at a given location i.e. species already established elsewhere in Australia but not recorded at that location; and (2) to detect target species not previously recorded in Australia that are known to be pests elsewhere.

#### **Additional Monitoring:**

The requirements for additional monitoring will be governed by the status of the pest within a particular jurisdiction and the components of the NCP that are relevant at the time. The preceding decision support frameworks (Figures 1-4) can be used to determine whether additional monitoring is required. Additional monitoring to be considered for the *Carcinus* NCP (summarised in Table 2) comprises 3 broad categories:

#### *1. Pest Prevention*

In relation to new incursions, additional monitoring sites may be recommended based on known vectors and transport pathways. Based on environmental tolerance information<sup>2, 73</sup>, only 9 of the 18 NMN locations are of relevance to *Carcinus* and 3 of these locations already have established populations. Consequently, additional monitoring sites should be considered by local jurisdictions on a case-by-case basis, considering transport pathways not considered in the NMN (e.g. recreational vessels, transfer of aquaculture gear etc.). When considering additional monitoring sites, priority should be given to sites in high value areas, particularly if strategies are in place to prevent translocation of *Carcinus* from a high risk source node to these high value areas. Given the apparent preference of *Carcinus* for shallow sheltered bays<sup>23</sup>, additional monitoring sites should focus on these habitats.

#### *2. Contingency Plan for new introductions*

Monitoring new incursions will involve surveys that determine the spatial extent of the new incursion, including monitoring of suitable habitats in areas adjacent to the known population of *Carcinus*. If an eradication attempt is initiated, monitoring will form a core component of the eradication program. Monitoring will involve quantifying *Carcinus* abundance and is likely to be required on an ongoing basis to ensure eradication success.

### 3. Impact management

If an impact management strategy is implemented a range of monitoring strategies should be considered depending on the management objectives (see Figure 4). If the objective of the control strategy is to reduce abundance of *Carcinus* within a high value area, for example, estimating the abundance of *Carcinus* should form a core component of the monitoring strategy. Monitoring of the impact itself is also recommended in these circumstances so the success of impact management can be assessed. If the high value area is based on the presence of an industry (e.g. aquaculture, fishery), monitoring should also include estimates of abundance for the species that the industry is based upon. Alternatively, if the high value area is based on environmental values, monitoring should involve quantifying the diversity and abundance of species of environmental value. Where possible, incorporating ‘treatment’ and ‘control’ areas is recommended so the effectiveness of management activities can be critically evaluated. Monitoring the rate of spread of *Carcinus* should also be considered within the ‘Impact Management’ category because the spatial extent of the pest is an important component of overall impact. It is also important when determining whether or not a significant range extension has occurred and consequently, whether or not an eradication attempt should proceed.

#### **Incorporating results from other monitoring programs into NIMPIS<sup>20</sup>:**

In many states there are programs in place involving monitoring of marine communities (e.g. community-based surveys, MPA surveys) and in some instances these programs collect information on the distribution and abundance of marine pests. Given the significant costs involved with monitoring programs, in circumstances where the surveys are appropriate for *Carcinus* it would be of considerable benefit if a mechanism was in place to incorporate this data into NIMPIS. Incorporating such data into NIMPIS may at least partly alleviate the need to carry out additional monitoring that may be recommended in the NCP and could represent a considerable cost saving.

There are also opportunities to incorporate industry based monitoring into NIMPIS. For example, aquaculture operations may monitor marine pests and in some jurisdictions this is a legislative requirement. In Tasmania one of the conditions of a marine farming licence is that: “The licence holder must notify the Department of Primary Industries and Water of the presence of any introduced marine pests within the lease area”. Similarly, in Victorian waters, aquaculture licence holders operating in marine waters are required to report the presence of suspected new incursions of exotic marine organisms at the specified site to the Secretary (or delegate), Department of Sustainability and Environment, within 24 hours of detection. It is recommended that this type of information should also be incorporated into NIMPIS. The information supplied not only provides potential information on distribution and abundance of *Carcinus*, but may also provide observations in relation to impacts. Where possible, state jurisdictions should engage industry to ensure collection of *Carcinus* data that will be of most benefit to management agencies. Providing quality information requires goodwill on the part of industry. Consequently it is very important that industry participants understand the value of the information they collect and are provided with adequate feedback to encourage continued cooperation. An efficient mechanism of extracting the relevant industry data compiled by state and territory governments and inputting it into NIMPIS is also needed.

While results from other monitoring programs are a potentially valuable resource, it should be noted that such data must meet minimum quality assurance standards before it is incorporated into NIMPIS. Alternatively, its use in a decision-making framework should be guided by an assessment of data quality.

**Table 2. Additional monitoring strategies that may be required for *Carcinus*.**

<b>NCP Section &amp; Monitoring objectives</b>	<b>Additional monitoring locations</b>	<b>Nature of data</b>
<b>1. Pest Prevention</b> - To detect new incursions  - To detect new incursions in high value areas	Select additional sites based on transport pathways and environmental conditions at recipient locations  Selected high value areas (e.g. aquaculture areas, Marine Protected Areas)	Presence/absence  Presence/absence
<b>2. Contingency Plan for new introductions</b> - To determine spatial extent of new incursion and whether additional populations exist  - To assess the effectiveness of eradication attempts	Site of infestation along with adjacent suitable habitats  Eradication site(s)	Presence/absence  Abundance
<b>3. Impact Management</b> - To assess effectiveness of impact management strategies      - To monitor the rate of spread	Monitor in locations with/without impact management strategies.      Various locations to establish the range of <i>Carcinus</i>	Abundance; Population estimates may require mark-recapture studies and monitoring of tagged <i>Carcinus</i> ;  Monitoring of specific impacts (e.g. impacted industries or biota)  Presence/absence

## H. A research and development strategy to improve vector controls, techniques for control and eradication of existing populations and detection and monitoring

A National strategy (2006-2016) for marine pest Research & Development has been completed<sup>74</sup> and includes a variety of research areas that should contribute to improved management of marine pests (including *Carcinus*) within Australia. The purpose of the R&D outlined in the *Carcinus* NCP is to highlight key R&D areas that will specifically enhance the performance of the plan, rather than presenting a comprehensive list of potential research areas. Most of the key R&D areas (summarised in Table 3) have been highlighted previously in the relevant decision support frameworks (Figures 1-4). In the long-term the proposed R&D will reduce uncertainty associated with the decision-making process and lead to more efficient investment of resources. Table 3 also includes a scheme for prioritising the proposed R&D based upon the importance of the research area to the NCP, its cost effectiveness and feasibility. It must be emphasised that the R&D areas and their relative priority is likely to change through time, so it is vital that a flexible approach is maintained. For example, the proposed R&D strategy does not include mitigation strategies for aquaculture activities because impacts on this industry are currently considered minimal. If more significant impacts on aquaculture are identified in the future, mitigation of impacts is likely to be central to management and this may warrant R&D investment.

A brief justification of the inclusion of the proposed R&D areas is provided for the relevant sections of the *Carcinus* NCP:

### **Pest Prevention**

Understanding the effectiveness of existing management arrangements is an important component of the R&D strategy, since the requirement for additional pest prevention measures will be largely determined by the success of these strategies. Given the potential importance of aquaculture activities as a vector for *Carcinus* spread, it is particularly important that an assessment of the likely efficacy of the proposed guidelines be conducted (Table 3; PP1).

### **Contingency Plan for new introductions**

While a range of resources are available to managers to assist in dealing with new introductions, publicly acceptable methods generally have a low probability of success against established pests<sup>70</sup>. Development of innovative tools to eradicate and/or control *Carcinus* populations should therefore be an on-going research priority, despite the technical challenges associated with eradicating a mobile species in an open marine environment (Table 3; CP1). Understanding the capacity for natural *Carcinus* spread is another key research question that has significant implications for management (Table 3; CP2). Addressing this question will provide an indication of the likely spatial extent of impact and is also of critical importance when deciding whether or not an emergency eradication response should proceed.

**Table 3. Summary of R&D strategy including a relative ranking system for prioritising research efforts. Scores for a range of assessment categories were summed to provide the overall priority score and allow a relative priority ranking to be assigned to each R&D area. Scores 0 = low, 5 = high, for assessment categories and relative priority ranking. Where appropriate, the relevant decision support framework figures are referenced to demonstrate how the proposed R&D areas will aid the decision-making process. Estimated indicative costs to complete each R&D section are also provided under the ‘cost effectiveness’ category. Since it is not possible to quantify benefits of each R&D area, cost effectiveness cannot be determined in quantitative terms. Instead, research areas requiring less expenditure have been prioritised at a higher level to reflect the likelihood that research funding will be limited.**

NCP section	R&D area ( <i>Relevant decision support framework</i> )	Relative importance to NCP	Cost effectiveness (indicative costs \$'000)	Technical Feasibility	Priority score	Relative priority
<b>Pest Prevention</b>	PP1. How effective are the aquaculture best practice guidelines for biofouling in reducing translocation risk? ( <i>Figure 2</i> )	4	4 (75)	4	12	<b>4</b>
<b>Contingency Plan for new introductions</b>	CP1. Development and testing of novel eradication/control tools ( <i>Figure 3</i> )	5	2 (200)	1	8	<b>1</b>
	CP2. What is the capacity for natural <i>Carcinus</i> spread? ( <i>Figures 1, 3</i> )	5	3 (100)	2	10	<b>2</b>
<b>Impact management</b>	IM1. What are the economic impacts of <i>Carcinus</i> in Australia? ( <i>Figure 4</i> )	5	5 (50)	3	13	<b>5</b>
	IM2. What are the environmental impacts of <i>Carcinus</i> on mainland Australia? ( <i>Figure 4</i> )	5	1 (300)	3	9	<b>1</b>
	IM3. Improved understanding of invasion process, including the role of native predators in conferring invasion resistance and the parameters that limit the distribution of <i>Carcinus</i> ( <i>Figure 4</i> )	4	2 (200)	4	10	<b>2</b>
<b>Monitoring</b>	M1. Gene probe development	2	5 (50)	4	11	<b>3</b>

### **Impact management**

Understanding the economic (Table 3; IM1) and environmental impact (Table 3; IM2) of *Carcinus* is vital because it plays a pivotal role in determining whether or not control actions should be pursued. A critical question when deciding whether or not a management response is required is “Do benefits of impact management exceed costs” (see Figure 4). Understanding impacts of *Carcinus* is potentially complex and may differ depending on the region concerned. For example, *Carcinus* appears to have a much greater environmental impact in Tasmania compared to mainland Australia<sup>38</sup>. Consequently, local studies are required with local predators and competitors.

Improved understanding of the invasion process, including the role of native predators in conferring resistance is recommended as a key research area that may lead to an increased range of control options (Table 3; IM3). Increased understanding of the ecology of *Carcinus*, including definition of the parameters that limit its distribution may also allow prediction of areas most vulnerable to invasion and better allocation of monitoring and control efforts<sup>33</sup>. While this fundamental biological research has the potential to lead to a greater range of impact management options, it should be noted that it by no means guarantees a solution to an introduced species problem<sup>75</sup>.

The importance of human-mediated disturbance is also important when assessing impact and prioritising management activity. If *Carcinus* requires disturbance to invade it is less threatening to the integrity of natural communities than if it is capable of invading undisturbed habitats (see Figure 4). This is a particularly important research question, since it has been speculated that in some parts of Australia *Carcinus* is only present in degraded habitats<sup>76</sup>.

### **Monitoring**

A variety of research and development issues in relation to monitoring and improved detection of new incursions are addressed in the National R&D strategy<sup>61</sup> and these will be applicable to *Carcinus*. One research area that is considered a priority for the *Carcinus* NCP is development of genetic probes, which are a potentially useful tool in detecting new incursions. Gene probes have been developed for a number of marine pests and it is recommended that future R&D includes development and testing of a *Carcinus* specific gene probe (Table 3; M1). It should be noted that a review of the utility of gene probes for marine pest monitoring has recently been commissioned by DEWHA. As a consequence, the relative priority of gene probe development with respect to the *Carcinus* NCP should be reassessed following the recommendations of the review.

### *I. Public awareness and education strategies for the species*

The Communications and Awareness Strategy for the National System is currently under development. While the activities planned are not species-specific, their implementation should generally be effective in meeting a number of the objectives of the *Carcinus* NCP. For example public awareness and education strategies aimed at reducing the spread of marine pests through management of biofouling will be applicable to *Carcinus*. Additional strategies which should be considered to enhance the effectiveness of the *Carcinus* NCP include:

#### **Additional strategies – Pest prevention**

Additional public awareness strategies may include targeted public awareness campaigns directed at high risk nodes where *Carcinus* is already established (e.g. ports, marinas and boat launching facilities) to reduce the risk of further translocation events. The proximity of transport vectors to high value locations such as aquaculture areas, important fisheries habitats and conservation areas may also warrant additional targeted public awareness strategies at the local level. Of the potential transport vectors, aquaculture and fishing (commercial and recreational) activities probably represent the greatest risk for translocation of *Carcinus*. If additional public awareness strategies are developed, it is vital that these sectors are targeted.

#### **Additional strategies – Contingency plan for new introductions**

Early detection of new incursions is a critical factor in the success of eradication programs and the public can play a key role in this regard. Detection of new *Carcinus* incursions is reliant upon an understanding of current distribution patterns and whether or not a ‘significant range extension’ has occurred. This is a complex issue when considering public awareness, for two main reasons. Firstly, spatial extent and spread is subject to change so public awareness strategies need to reflect this dynamic situation. Secondly, an improved understanding of likely natural spread is required to determine whether a ‘significant range extension’ has occurred. As outlined previously scientists and managers need to clearly define ‘significant range extensions’ for *Carcinus* so the public can be properly educated/informed.

Because of the potentially dynamic nature of the spread and spatial extent of *Carcinus*, monitoring results will be incorporated into a new web-based system (i.e. via NIMPIS), including locations that would be considered ‘significant range extensions’. Clearly for this to be effective, the marine pest monitoring database under the National System must include the most up-to-date information available.

In relation to new *Carcinus* incursions, public awareness strategies in relation to emergency response are covered in the Australian Emergency Marine Pest Plan<sup>49</sup> (EMPPPlan).

#### **Additional strategies – Impact management**

Additional public awareness and education strategies will require development on a case-by-case basis depending on the jurisdiction and impact management activities that are implemented. Information to be disseminated should highlight the threat posed by *Carcinus*, the control approach (e.g. trapping) and the likely benefits of impact management (e.g. biodiversity, commercial activities).

*J. Agreed funding mechanisms*

The Intergovernmental Agreement (IGA) on a National System for the Prevention and Management of Marine Pest Incursions addresses the agreed funding mechanisms for implementing National Control Plans. In particular, Section 24.1 states that:

‘The Parties agree that funding for the ongoing management and control measures of the National System will need to be provided by the Parties in accordance with the shared and co-operative measures agreed through National Control Plans on a case by case basis. That Parties acknowledge that, where relevant, Partnership Agreements should be developed to provide funding support for ongoing management and control measures based on the level of benefit of the arrangement to stakeholders and government.’

Within the IGA a “Partnership Agreement means the agreement by that name (including any attachments or annexes to that agreement) between a stakeholder organisation and governments with respect to implementing and/or funding the National System”.

### *K. A multi-year budget*

Providing accurate budget estimates is problematic because costs will depend on the management actions that are conducted by the relevant jurisdictions. There are also significant uncertainties associated with budget estimates for each section of the NCP. For example, costs associated with monitoring will depend on the need for additional monitoring sites and whether or not impact management activities required. Providing a budget for impact management (e.g. trapping programs) is complex because costs will depend upon numerous factors such as the spatial extent of the population, the location (i.e. accessible versus remote) and depth (e.g. are boats required?). The ability to utilise volunteers also has a strong influence on the budget required to implement NCP activities (see Table 4, Impact management) but it should be noted that there are potentially significant occupational health and safety issues associated with use of volunteers.

Despite the uncertainties associated with provision of budgets, indicative costs for management activity within the relevant NCP sections have been provided in Table 4. These are intended as a rough guide for managers to assess the cost of implementing the various management activities outlined in the plan. A case study for impact management has been included in the budget based on control of *Carcinus* within a small bay. A trapping program is proposed as an example because it is considered the most effective of the currently available control options.

To provide the most realistic case study possible, the size of the bay, trapping intensity and trapping frequency closely matches the control program recently undertaken in Bodega Bay Harbour (see section F). Preliminary discussions with scientists involved with *Carcinus* control in North America indicate that the major costs are associated with monitoring (C. de Rivera, Portland State University, pers. comm., November 2007). The *Carcinus* removal itself can be achieved for relatively little cost using suitably trained volunteers.

Note that salary for a project officer at a nominal level of 0.5 FTE has been included to coordinate management activities outlined in the plan. It is envisaged that a full time position would incorporate management of other marine pest species at a national level – allocation of effort for each particular species would be based on the funding made available for each species.

Table 4. Indicative budget for *Carcinus* National Control Plan (as at January 2008).

NCP section	Budget items	Likely Costs (\$AUD)	Funding arrangements/ expected financier
<b>Pest prevention</b>	No applicable budget items	NA	NA
<b>Contingency plan for new introductions</b>	Eradication of new incursion (including on-going monitoring)	\$860 000 – 263 million per incursion <sup>2</sup>	Interim cost-sharing arrangements are in place
<b>Impact management</b>	Case study example 1. Trapping program <sup>a</sup> – fully funded. Equipment (\$490 <sup>b</sup> ), Bait (\$1040 <sup>c</sup> ), Staff (\$52 000 <sup>d</sup> ), Car hire (\$5200 <sup>e</sup> ), Consumables (\$500 <sup>f</sup> ).	\$59 230 per year	State/territory governments
	Case study example 2. Trapping program <sup>a</sup> – volunteer based. Equipment (\$490 <sup>b</sup> ), Bait (\$1040 <sup>c</sup> ), Car hire (\$5200 <sup>e</sup> ), Consumables (\$500 <sup>f</sup> ).	\$7230 per year	State/territory governments
	Habitat management (e.g. maintain integrity of native predator populations)	Uncertain	State/territory governments
<b>Monitoring</b>	Additional monitoring sites to detect new incursions. -Requirement for additional monitoring sites will depend on jurisdiction and vectors operating.	\$10 000- \$20 000 <sup>g</sup> per site per year	State/territory governments
	Monitoring economic impacts to evaluate impact management strategy	Uncertain – depends on data collected	To be advised
	Monitoring environmental variables to evaluate impact management strategy E.g. Quarterly sampling of control and impact bays <sup>h</sup> . Equipment (\$490 <sup>b</sup> ), Bait (\$320 <sup>c</sup> ), Field staff (\$16 000 <sup>d</sup> ), Data analysis and write-up (\$30 000 <sup>i</sup> ) Car hire (\$1600 <sup>e</sup> ), Consumables (\$500 <sup>f</sup> ).	\$48 910 per year	To be advised
	Monitoring rate of spread	\$10 000 per year	To be advised
<b>R&amp;D</b>	Various R&D areas (see Table 3)	\$0.975 million <sup>1</sup> over 3 years	Commonwealth & State/territory governments
<b>Communications strategy</b>	Depends on the impact management measures implemented	Uncertain	
<b>Overall co-ordination</b>	Salary for project officer (0.5 FTE)	\$50 000 per year	To be advised

<sup>a</sup> Based on population occurring in small, shallow bay ( size < 5 km<sup>2</sup>, wadeable), weekly trapping (52 surveys) using 40 traps/trapping run; <sup>b</sup> 40 traps including 20 opera house traps (\$8.50/trap) & 20 crab nets (\$16/trap); <sup>c</sup> 100 g bait/trap, pilchards \$5/kilo; <sup>d</sup> Field biologists cost \$500/day, 2 biologists/survey; <sup>e</sup> Car hire \$100/day;

<sup>f</sup> Consumables including waterproof paper, slates, stationary; <sup>g</sup> Cost effectiveness could be improved by surveying multiple pest species; <sup>h</sup> Based on 4 sites, 'impact' site and three control sites, total of 16 surveys; <sup>i</sup> Data analysis and write-up by suitably qualified scientist; <sup>j</sup> Assumes all priority R&D areas are addressed; NA = not applicable.

*L. A mechanism for monitoring of implementation of the National Control Plan and ongoing evaluation*

An important component of the NCP involves monitoring implementation of the plan and critical evaluation of its effectiveness. Proposed performance indicators have been identified and these are provided in Table 5.

**Table 5. Potential performance indicators for the *Carcinus* National Control Plan. Note that monitoring was not included as a criterion in its own right because the proposed performance indicators are inextricably linked to monitoring (e.g. Pest prevention - number of new populations; Emergency response - detection of new invasions; Impact Management – change in abundance over time).**

<b>Criteria</b>	<b>Objectives</b>	<b>Performance Indicators</b>
<b>Pest prevention</b>	(i) Prevent significant range extensions (ii) Prevent new populations establishing within current range of natural spread (iii) Reduce translocation risk by improved vector management (iv) Development of additional strategies as required	Number of significant range extensions Number of new self sustaining populations minimised, especially in high value areas Uptake of existing or proposed guidelines Number of additional pest prevention measures developed
<b>Contingency plan for new introductions</b>	(i) Detect new invasions early enough to enable rapid response (ii) Eradication of new incursions (iii) Increase range of effective eradication techniques	Proportion of invasions detected in time for rapid response Eradication of new populations prior to spawning Number of effective eradication tools evaluated and available
<b>Impact Management</b>	(i) Prioritise <i>Carcinus</i> impact management relative to other threats (ii) Reduce impacts in high value areas (iii) Reduced population size & lowered reproductive output within high risk source regions (iv) Long-term reduction in <i>Carcinus</i> abundance	<i>Carcinus</i> impact management prioritised based on known and likely impacts Detectable reduction in impacts Detectable reduction in reproductive output in high risk source regions Decrease in abundance over time (e.g. 10 years)
<b>R&amp;D</b>	(i) Implement priority R&D areas highlighted in plan (ii) Re-evaluate R&D in response to research outcomes	Number of priority R&D areas completed Regular assessment and prioritisation of R&D activities
<b>Public education</b>	(i) Increased public awareness (ii) Increase effective community involvement	Increased community knowledge of risk, impact & prevention/control measures Increased community involvement in detection and impact management activities; Increase in proportion of informative reports (e.g. correct ID's)

*M. Stated commitments of relevant parties, including Australian Government, State/Territory governments, local government, industry and NGOs*

The Intergovernmental Agreement on a National System for the Prevention and Management of Marine Pest Incursions (IGA) addresses the stated commitments of the Australian Government and the State and Northern Territory Governments in implementing the National Control Plans. In particular, Section 16a-16c states that:

The Parties will implement the ongoing management and control component of the National System as follows:

- (a) each Party accepts responsibility for ongoing management and control activities for agreed pests of concern within waters under its control;
- (b) National Control Plans, reflecting an agreed national response, will be developed to reduce, eliminate or prevent the impacts (including translocation) of agreed pests of concern; and
- (c) each Party will use reasonable endeavours to develop and implement the relevant National Control Plans;

(Currently, all States and the Northern Territory, with the exception of NSW, have signed the IGA. NSW have, however, agreed to intent of the IGA and are only concerned about the funding model in regards to a marine pest outbreak. This situation may change in the future.)

Agreements to implement a control plan by a jurisdiction may involve consultation and cooperation with other relevant jurisdictions (i.e., other State and Territory Governments) and with relevant local government, industry and the non-government organisations. These arrangements will depend on the nature of the particular control operation and will vary between operations.

Agreed Control Plan actions by the Australian Government, State and Territory Governments and stakeholder agencies will be identified as part of a National Implementation Strategy. The National Implementation Strategy document will be maintained independently of the National Control Plan documents, and updated to reflect current and proposed commitments.

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## **APPENDIX I – List of available resources to assist with implementation of NCP**

### **Pest Prevention**

- Australian domestic ballast water arrangements (under development)
- Biofouling Guidelines (guidelines for many sectors still under development)
  - National Biofouling Management Guidelines for Non-trading Vessels
  - National Biofouling Management Guidelines for the Petroleum Production and Exploration Industry
  - National Best Practice Management Biofouling Guidelines for the Aquaculture Industry
  - Best Practice Guidelines for Domestic Commercial Fishing Vessels
  - National Best Practice Management Guidelines for the Prevention of Biofouling on Commercial Vessels
  - National Biofouling Management Guidelines for Domestic Recreational Vessels
  - National Best Management Practice Biofouling Guidelines for Nodes- Commercial Trading Ports
  - National Best Management Practice Guidelines for Abandoned, Unseaworthy and Poorly Maintained Vessels
  - National Best Practice Management Biofouling Guidelines for Nodes- Boat Harbours, Marinas and Boat Maintenance Facilities

### **Contingency Plan for New Introductions**

- National Introduced Marine Pest Information System<sup>20</sup> <http://crimp.marine.csiro.au/nimpis>
- The Web-Based Rapid Response Toolbox<sup>49</sup>  
<http://crimp.marine.csiro.au/NIMPIS/controls.htm>
- Pre-Developing Technology for Marine Pest Emergency Eradication Response<sup>50</sup> (in review)
- Rapid Response Manual – *Carcinus maenas* (under development)
- Australian Emergency Marine Pest Plan<sup>48</sup> (EMPPPlan)
- National System Marine Pest Identification Card – *Carcinus maenas* (under development)

### **Monitoring**

- Australian Marine Pest Monitoring Guidelines: Version 1 (December 2006)<sup>71</sup>
- Marine Pest Monitoring Manual: Version 1 (December 2006)<sup>72</sup>