An Australian Government Initiative

NATIONAL CONTROL PLAN

Asian bag or date mussel
Musculista senhousia

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

This collaborative effort is supported by the Australian Government, state and Northern Territory governments, marine industries, researchers and conservation groups.

Australian Government

National Control Plan for the Asian bag or date mussel *Musculista senhousia*

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 Asian date mussel *Musculista senhousia*.

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LIST OF ACRONYMS

CCIMPE	Consultative Committee on Introduced Marine Pest Emergencies
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 *Musculista senhousia*, 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 (NCPs) 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 *Musculista senhousia* (hereafter referred to as *Musculista*) and includes:

- practical management actions and cost effective approaches to improve any measures currently in place to prevent, control or manage the impacts of the 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[1]. 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 Research and Development (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 *Musculista* within Australian environments.

The overarching decision support framework for *Musculista* 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 *Musculista*, 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.

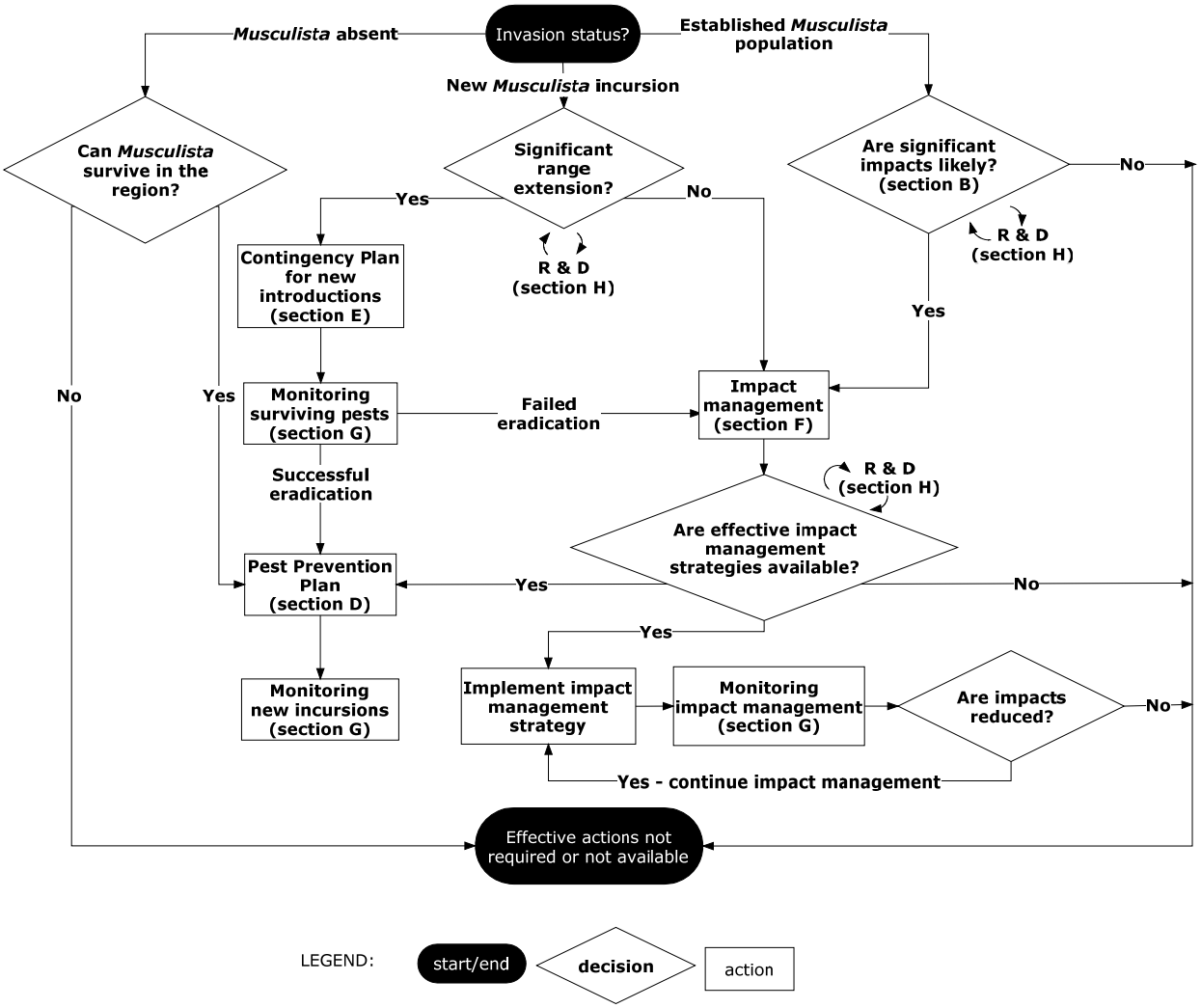

Figure 1. **Overarching decision support framework for *Musculista* management. There is inherent uncertainty associated with some questions (e.g. Can *Musculista* survive in the region?) so decisions must be made on the best available information (e.g. species range mapping data[2]). Note that if effective 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 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[3] (section 5.2 "Priorities for management"). As outlined in the Toolkit[3], 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 *Musculista* to environmental, social and economic values should the species not be controlled. It is based upon an assessment of demonstrable and potential impacts of *Musculista* against the relevant CCIMPE criteria[4] (i.e. economy, environment, human health, amenity):

Economy:

Impacts in native and invaded ranges

In its native range *Musculista* has been reported to be associated with mortality of commercially important clams[5, 6] (*Ruditapes philippinarum*).

The introduction of *Musculista* in Italy has been claimed to create heavy impacts on commercial shellfish industries (based on the clams *Ruditapes philippinarum* and *Tapes decussates*) through the reduction of shellfish growth and survival[7]. However, recent experimental evidence concluded that the presence of *Musculista* has no effect on these clam species[7]. Mistri (2004)[7] notes that the economic impacts attributed to *Musculista* are confounded by biotic responses to other potentially interrelated changes in ecosystems, including resource overexploitation, pollution and habitat deterioration.

Impacts in Australia

The economic impacts of *Musculista* in Australia are poorly understood. In its invaded range *Musculista* has a preference for soft sediment habitats and typically occurs on intertidal mudflats[8-10], in saltmarshes[11], and in deeper subtidal regions of estuaries[10]. The most likely impacts associated with *Musculista* are on fisheries and/or aquaculture operations that occur in these habitats.

The presence of *Musculista* 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 (combined average beach value of $AUD 234K per year, based on average earnings 2001-2005[12]). Other cockle fisheries that harvest animals from high energy surf zones (e.g. Goolwa cockle *Donax deltoides*[13]) are not likely to be affected by *Musculista*, due to its preference for low energy, sheltered habitats. Similarly, scallop fisheries are unlikely to be influenced by the presence of *Musculista* because of differences in preferred habitat. Most commercial scallop fisheries in Australia operate on open coasts (e.g. Tasmanian scallop fishery[14]), so interactions between *Musculista* and scallops are not considered likely.

There are no reported negative interactions between *Musculista* and aquaculture operations in Australia. Interactions with aquaculture operations reported elsewhere have involved species such as clams that are grown directly on the seabed, however, such practices are not currently used in Australia. While direct effects of *Musculista* on aquaculture industries are presently considered minimal, *Musculista* could potentially have indirect effects as a competitor of filter-feeding species (e.g. oyster/mussels), resulting in reduced growth rates and productivity.

Environment:

Impacts in invaded range

Musculista can attain very high densities in both intertidal and subtidal soft sediments[15, 16]. Typical abundances are 5000 - 10 000 m^{-2}, but densities in excess of 15 000 m^{-2} have been reported in North

America[17-19]. When present in high densities, byssal threads produced by *Musculista* form cocoons that intertwine and form a 'mat' that contains shells, sediment, algae, and detritus[20-22]. Formation of these mats results in significant habitat alteration including changes in the character of associated sediments[21]. Once established, *Musculista* mats can have profound effects on native marine communities. *Musculista* can inhibit larger, and facilitate smaller, infaunal species[20, 21, 23, 24]and invasion typically results in inhibition of suspension-feeding taxa and enhancement of detritivores[25].

Musculista can also have negative effect on a dominant temperate marine angiosperm, eelgrass (*Zostera marina*)[19]. Eelgrass is widely distributed in coastal regions of the northern hemisphere and supports a highly productive and diverse community[26]. In North America, significant research efforts have been associated with understanding the complex interactions between *Musculista* and eelgrass[19-21, 23, 24, 27-29]. In southern California, *Musculista* is found at mat-forming densities only in areas where eelgrass beds are fragmented, sparsely vegetated or absent[19, 28]. Where eelgrass is dense, the growth and survival of *Musculista* is poor[19, 28]. Dense eelgrass influences the distribution of *Musculista* through food limitation: the eelgrass canopy reduces water flow speeds, thus decreasing the availability of phytoplankton food[27, 28]. In circumstances where eelgrass is replaced by *Musculista*, there may be long-lasting effects on the ecosystem, including lowered benthic primary production, and reduced abundance of native bivalve species[27]. Extensive *Musculista* mats also have the potential to alter the abundance and distribution of local phytoplankton assemblages[27].

While effects of *Musculista* on benthic communities have been observed in New Zealand, impacts are considered short-lived and relatively minor, due to the ephemeral nature of *Musculista* beds[20]. Although accumulated sediments may persist for some time after *Musculista* has died, it is believed that they will eventually be washed away by tidal currents. The dramatic impacts caused by the ecologically similar zebra mussel in freshwater habitats in the United States are considered unlikely to occur in coastal habitats of New Zealand[20].

While there are proven impacts attributable to *Musculista* invasion, it should be noted that in both its native and introduced range it thrives mostly in eutrophic environments (lagoons and estuaries) affected by excessive nutrient loads and macroalgal blooms[7]. It is therefore likely *Musculista* exploits naturally disturbed, sparsely occupied environments, rather than actively displacing existing species.

Impacts in Australia

The environmental impacts of *Musculista* in Australia (refer to NIMPIS[30] for details on *Musculista* range) remain poorly known. Based on sea water temperature *Musculista* has the potential to become extensively distributed across Australia[2]. Given the link between fragmentation of eelgrass beds and *Musculista* invasion in the northern hemisphere, similar interactions could be expected to occur in Australia. This should be cause for concern, since there is significant evidence for decline of seagrass beds across Australia associated with human-mediated disturbance[31].

Human Health & Amenity:

There are no reported or anticipated human health concerns associated with establishment of *Musculista* populations. Impacts on amenity are considered to be relatively minor, but negative effects on biodiversity and the aesthetic values of the marine environment would potentially affect tourism and recreational values of coastal areas.

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 NCP for *Musculista* was finalised in 2006[32]. The business case summarises the likely threat and impacts of *Musculista* 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 *Musculista*, 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 Musculista

Musculista 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:

In high densities the byssal threads of *Musculista* form mats that significantly alter the habitat and potentially exclude large native species and facilitate smaller, infaunal species. It can also have a negative effect on eelgrass (*Zostera marina*)[19]. It is present in five out of 60 Australian marine bioregions (as defined in the Interim Marine and Coastal Bioregionalisation for Australia – IMCRA[33])

Potential for further introductions and spread of Musculista

Musculista 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 harbours and ports, and the hull surface area of vessels that enter ports (which increases biofouling potential). *Musculista* has significant potential to invade additional places in IMCRA bioregions where the species are already present, as well as bioregions that have not yet been invaded.

Musculista 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 *Musculista* to establish pest populations. On the basis of water temperature it has the potential to invade 25 bioregions (currently present in five).

Benefits of National Control Plans

NIMPCG considers that the implementation of a NCP for *Musculista* 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 *Musculista* 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

Control measure	**National System Component**	**Annual Cost**
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 *Musculista*, the benefit to cost ratio was 0.4 where eradication of the species was not considered possible and 1.0 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 *Musculista*, including existing arrangements, is shown in Figure 2. Reducing the risk of ballast water-mediated translocation of *Musculista* 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. *Musculista* has been nominated as one of the species for which ballast water management between Australian ports will be required.

Biofouling:

Musculista has the potential to be transferred via biofouling. National best practice management guidelines for management of biofouling are currently being developed for various marine sectors[34] including domestic recreational vessels, aquaculture, commercial fishing and petroleum industries. A number of measures are available to reduce translocation risk associated with hull fouling including regular slipping and dry-docking of the vessel to enable inspection, repair or renewal of the anti-fouling coating, in-water inspection by divers and undertaking in-water clean (note that prior approval to undertake in-water cleaning is required from the relevant state/territory authority) or dry-docking as necessary, inspecting internal seawater systems, cleaning strainer boxes, and dosing or flushing of these systems. Adherence to the proposed guidelines should ensure that translocation risk is reduced.

Transfer of aquaculture equipment and seedstock is considered a high-risk vector for entraining *Musculista*. Oyster farming activities are considered most likely to entrain *Musculista*. Oysters are routinely moved within and between states[35] so it is important that biofouling guidelines for the aquaculture industry are effective in eliminating *Musculista* from stock and/or equipment. A range of techniques are available[36] including a number of simple and environmentally friendly methods (e.g. freshwater immersion, air drying) that have been trialled against the introduced seaweed *Undaria pinnatifida*[36]. The efficacy of potential treatments to reduce translocation of *Musculista* associated with aquaculture activities remains unknown (section H).

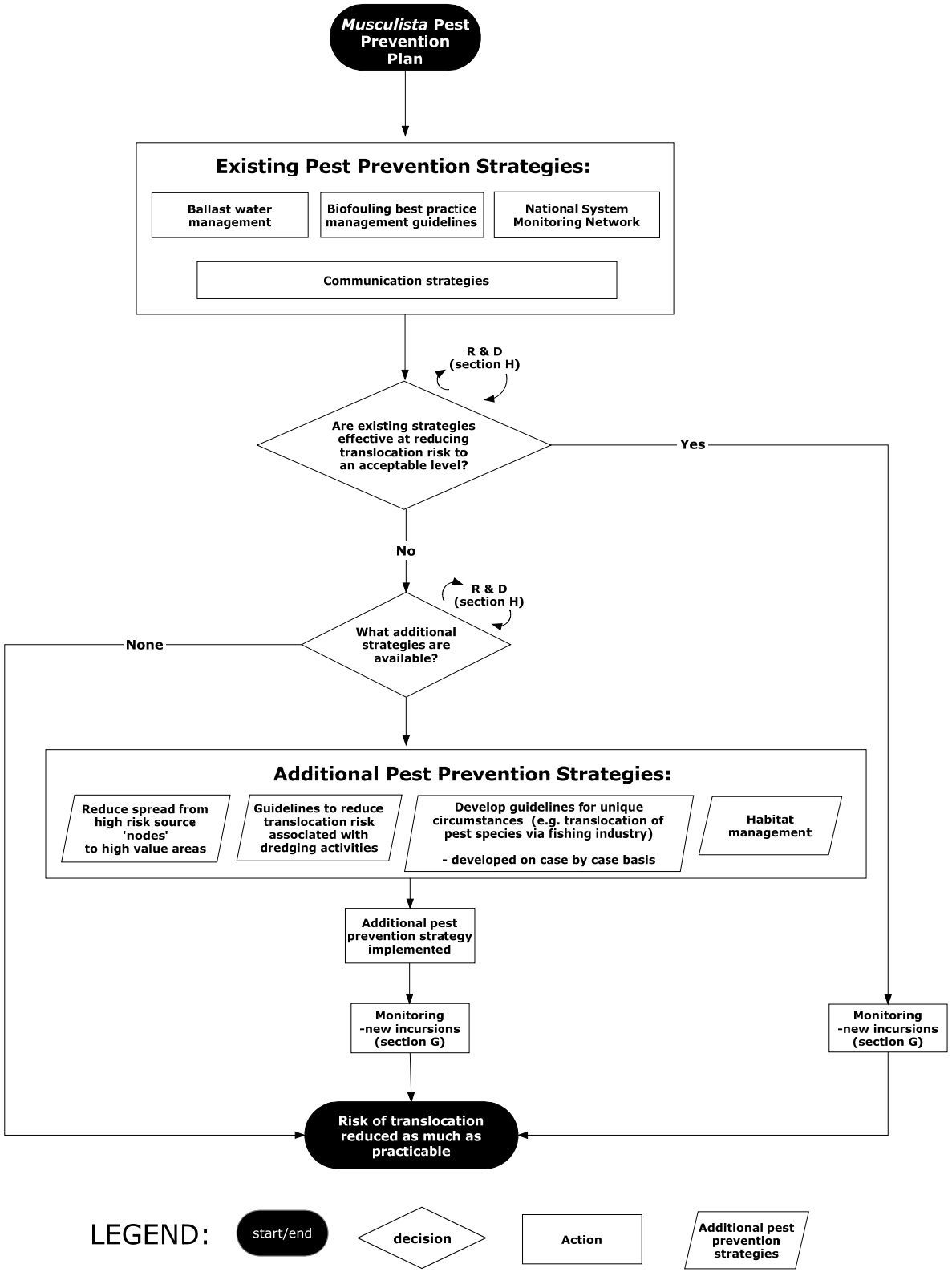

Figure 2. Pest prevention plan and decision support framework applicable to *Musculista*.

Additional Pest Prevention Strategies:

- Transfer of *Musculista* from high risk nodes (e.g. infested ports, marinas) to high value areas (e.g. MPAs, important aquaculture regions) may warrant additional pest prevention measures. For example, sterilisation of hull and internal seawater systems might be recommended for vessels travelling to high value areas. This kind of hull sterilisation could be conducted 'in-water' by wrapping vessel hulls and applying a chemical treatment (e.g. Coutts and Forrest 2005[37]). Effective public awareness and communication campaigns will be an integral component of this strategy.
- Dredging operations for port maintenance and capital works could serve as a vector for *Musculista*. Dredging activity could lead to localised redistribution of *Musculista*, but more importantly, further spread could occur if spoil is lost overboard while enroute to the disposal site. Existing regulations controlling dumping of dredge spoil (e.g. *Sea Dumping Act 1981*[38]) may at least partly reduce the spread via this vector. Dredging activity during ballasting operations could also increase the risk of the uptake of larvae in ballast tanks and it would be preferable if ballasting operations are not carried out whilst dredging is under way. Therefore, guidelines for dredging operators should be considered as an additional strategy to reduce the risk of *Musculista* translocation, especially for high risk source 'nodes'.
- 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[39]. 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 *Musculista* entrainment and translocation associated with fishing or related activities.
- Given that native predators and competitors provide resistance to *Musculista* invasion[27, 40, 41], habitat management should also be considered as part of an integrated strategy to prevent further *Musculista* spread. Where human activity can be linked to loss of predators or competitors, indirect control options to prevent further spread may exist by focusing efforts to minimise anthropogenic disturbances. For example, preventing fragmentation of macrophyte beds and developing and enforcing water quality standards will be not only benefit the broader ecosystem, but may also prevent further spread and associated impacts of *Musculista*[27].

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 *Musculista* is provided in Figure 3. The decision on a national response to eradicate new introductions or range extensions of *Musculista* is dependent on whether or not a 'significant range extension' has occurred. As defined in the CCIMPE Standard Operating Guidelines[4], 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)[42].

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 *Musculista* incursions. The National Introduced Marine Pest Information System (NIMPIS) rapid response toolbox[43] 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[44]. 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[45].

The range of treatment options available for a marine pest emergency involving *Musculista* depends on the area of infestation and the environmental circumstances associated with the incursion. Unless the *Musculista* population is contained, the range of eradication options is likely to be extremely limited because of its small size (< 30 mm) and ability to form high densities on both soft sediments and artificial structures. As applies to all marine pest emergencies, the most effective way to deal with a new *Musculista* incursion is to detect it early and eradicate or contain the population before further spread occurs.

Some key information gaps remain that should be addressed to improve emergency eradication response(s) involving *Musculista*. For a successful eradication, it is vital that *Musculista* is removed

before spawning occurs, however, in Australian environments the spawning period remains unknown. Addressing this question is of particular importance because there is evidence of variability in reproductive dynamics between native and invaded regions. In its native range and in the Mediterranean, reproduction occurs seasonally (summer[46, 47]). In contrast, in California, USA it appears *Musculista* is capable of year-round recruitment[29].

Another important question for managers when responding to new *Musculista* 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[48]. In its native range, *Musculista* larvae remain in the plankton up to 21 days[29], however the larval period and capacity for natural dispersal in Australian environments remains unknown (see section H).

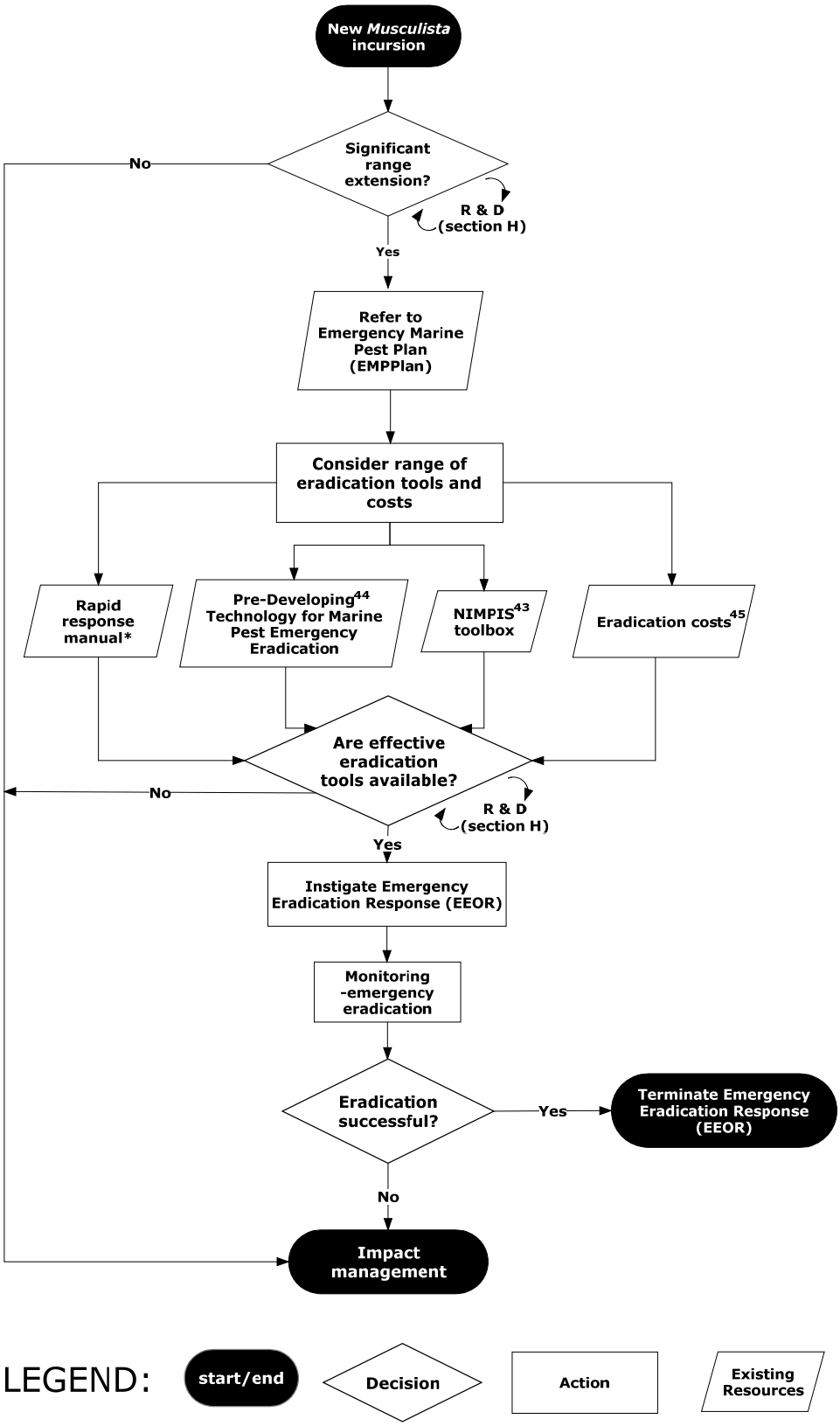

Figure 3. Decision support framework for new introductions of *Musculista* highlighting the currently available resources to assist the decision-making process. *Resources currently under development.

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 *Musculista* 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 *Musculista* 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 *Musculista* impact is likely to be in the 'none' category for economic impact and the 'low-moderate' category for environmental impact based upon the threat analysis (section B) and the scheme proposed in Figure 4.

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)[33]' should be consulted to identify areas of biological significance.

Currently available impact management options:

Control options are defined under three broad categories, including: (1) direct targeting of *Musculista*; (2) habitat management; and (3) impact mitigation. A summary of the efficacy and feasibility of currently available control 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 Musculista:

Physical removal

Options for direct control of *Musculista* populations are extremely limited due to its small size (< 30 mm) and ability to form high densities on both soft sediments and artificial structures. Where possible, control activities should aim to reduce *Musculista* population densities prior to spawning (although as noted in Section E reproductive dynamics are presently poorly known in Australia). Physical removal is one of the few available options for direct control of *Musculista*, but it should be recognised that there are significant limitations associated with physical removal methods. In intertidal habitats, *Musculista* can be removed from soft sediment habitats by raking[40], while on artificial substrates, *Musculista* could be removed via scraping in combination with a suction pump to collect mussels as they are dislodged[44]. Both methods are likely to be extremely labour-intensive and only suitable for localised reduction in population abundance. Dredging is another possible

control option for subtidal populations occurring on soft sediments. This could involve diver operated 'suction' dredges for small areas[44], or conventional dredges deployed from the surface for large areas. While dredging may result in short term decline in *Musculista* abundance, it is likely to have significant impacts on the broader benthic community and the environmental effects of an ongoing dredging program are not likely to be publicly acceptable. Furthermore, the effectiveness of dredging as an impact management measure is questionable for *Musculista*, given the species' ability to successfully colonise disturbed habitats[7].

Biological control

Biological control has been considered as a management option for other introduced species (e.g. *Carcinus maenas*[49], *Asterias amurensis*[50]), however, further research is required before it could be considered a serious control option against *Musculista*. 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[51]. 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.

Another form of biological control involves top-down control ("biocontrol") which may be achieved by introducing predators from the invader's native range[52]. More appealing is biocontrol via a native predator that learns to consume the invader, which eliminates the risk of unforeseen consequences for local species and communities that may arise from introducing a non-native predator[53]. This approach holds promise, particularly given that native species have been shown to be significant predators of *Musculista* in its invaded range[40, 52, 54, 55]. However, enhancement of *Musculista* predator populations has yet to be trialled as a control method for *Musculista*. Potential predators of *Musculista* also remain unknown in an Australian context (see section H).

Chemical control

While a range of molluscicides are potentially effective against marine pests[43], they are only likely to come under consideration in circumstances where the population is contained (e.g. marinas). For established *Musculista* populations in open systems, chemical application is not a practical impact management option because of the complexities associated with maintaining desired chemical concentrations and concerns associated with their broader impacts on the marine environment. These circumstances apply to most populations observed in Australia,

Wrapping/smothering techniques

A control option that may be considered for localised reduction of *Musculista* populations is wrapping/encapsulation of man-made structures. This method has been used as an eradication tool for introduced sessile invertebrates in New Zealand (e.g. *Didemnum vexillum*, *Styela clava*) and involves covering artificial structures with plastic[37, 56]. Anoxic conditions that develop beneath the wrap kill fouling organisms and this may be accelerated by addition of chemicals (e.g. chlorine, acetic acid). For *Musculista*, this could be considered as a means of reducing population size in a high risk source node. As with diver removal, this may be feasible in small ports, but for large commercial sized ports it would be a major on-going expense and is not likely to be a practical option. A similar smothering principle can be applied to natural substrates, however, obtaining an adequate seal on the benthos can limit the efficacy of the method[56]. While the efficacy of wrapping/smothering techniques against *Musculista* remains unknown, it is likely to be an effective method, given that *Musculista* is unable to survive in anoxic conditions[57]. While smothering may be considered as an option to reduce reproductive output from high risk source nodes, the smothering

process is also likely to kill a range of other organisms. As is the case with dredging, this provides substrate for further recruitment of opportunistic species (including *Musculista*). Consequently, to be effective as a control option it is likely that on-going treatments would be required.

(2) Habitat management:
While it has not been experimentally tested, there are links between human-mediated disturbance and invasion success for *Musculista*[7]. The link between disturbance and invasion success provides potential control options for *Musculista*. Where disturbance can be linked to human activity, it may be more effective to target the cause of the disturbance, rather than directly targeting the mussel. Disturbance to 'eelgrass' or 'seagrass' beds is probably the most important disturbance to consider in this context, since previous work has shown that patchy or fragmented eelgrass beds are vulnerable to invasion by *Musculista*[19, 28], while dense eelgrass inhibits invasion[19, 28]. Potential anthropogenic activities that may be responsible for seagrass loss[31] include eutrophication, sedimentation, toxicants, freshwater, physical damage and global warming.

It should be recognised that in situations where *Musculista* establishes following disturbance to eelgrass beds, it does not necessarily follow that native assemblages will recover once conditions return to normal. If loss of eelgrass beds occurs over large scales, recovery via natural processes is unlikely, since eelgrass relies primarily upon the vegetative growth of nearby plants for recolonisation[58] and seeds of eelgrass rarely disperse more than a few centimetres to meters[59]. In contrast, *Musculista* recruits into open space much more readily than eelgrass[29] and it is conceivable that a permanent transition from eelgrass beds to mats of *Musculista* could occur[60]. Under these circumstances, rehabilitating macrophyte beds should be considered for indirect control of *Musculista* populations. Research and development into macrophyte restoration and rehabilitation techniques has progressed considerably in recent years and a range of techniques are available[61]. Previous work has shown that the presence of *Musculista* can inhibit recovery of macrophyte beds, so rehabilitation techniques may need to be combined with thinning of *Musculista* mats[19].

Another potential habitat management option involves managing native predator populations. It has been suggested that when native predators of *Musculista* are targeted for commercial purposes (e.g. fishing[55]), resistance to *Musculista* invasion may be lowered and in these circumstances it is particularly important to ensure overfishing does not occur. Suspending harvesting of predators during the period of maximum *Musculista* population growth has been identified as a potential management option to control *Musculista* mats in Italy[55]. Further research is required to identify potential *Musculista* predators in Australian environments before this management approach can be considered a realistic control option.

(3) Impact mitigation:
The direct economic impacts of *Musculista* are currently considered minimal in economic terms. Impact mitigation measures may require development if circumstances change in the future. In locations where *Musculista* is present, serious caution should be exercised if aquaculture developments propose to grow animals directly on the seabed, since this is where *Musculista* impacts are considered most likely.

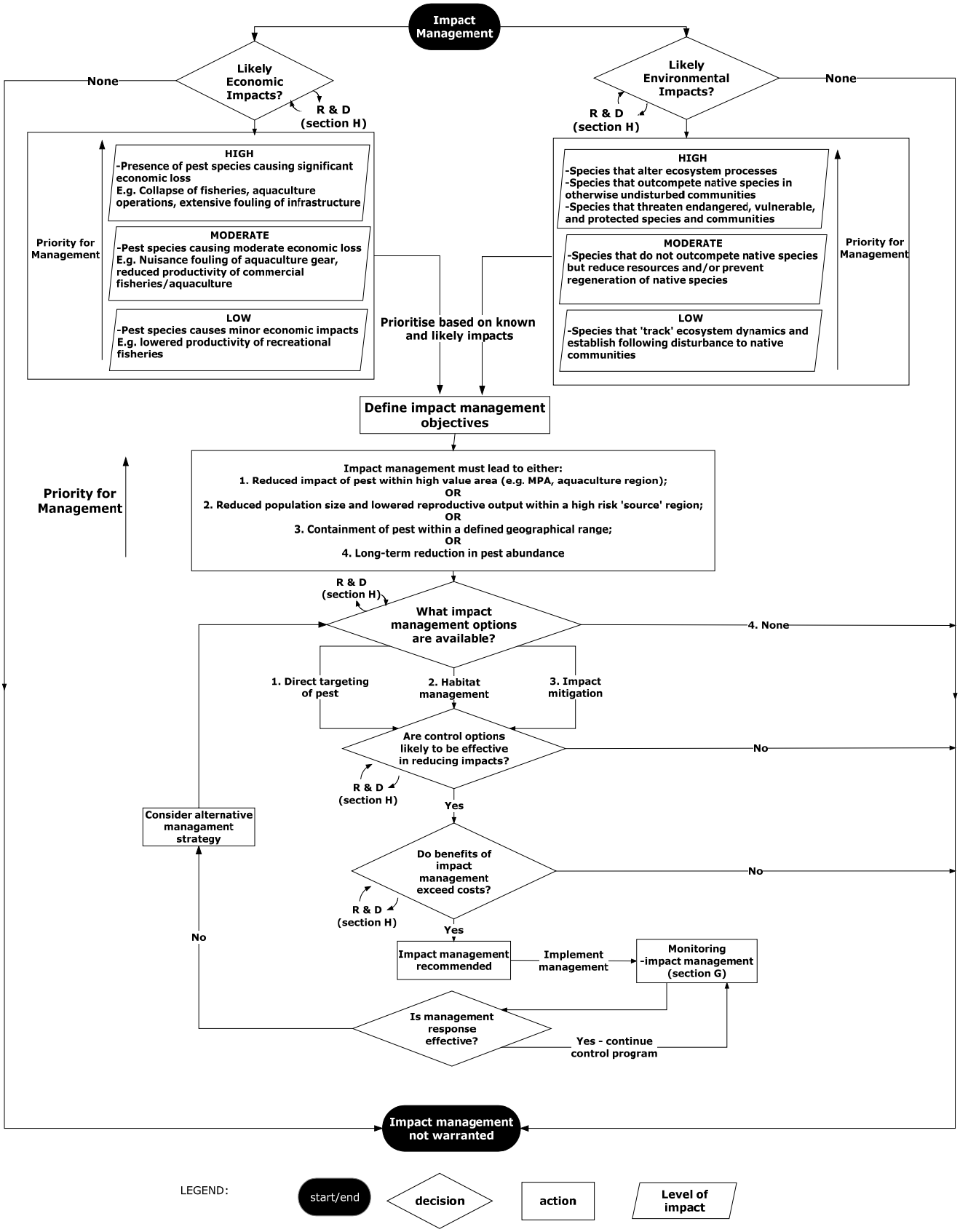

Figure 4. Impact management decision support framework applicable to *Musculista*.

Table 1. **Currently available impact management options considered suitable for *Musculista*. (Note that potential control options such as genetic control that are under development or are considered environmentally unacceptable are not included).**

Method	Likely Efficacy	Feasibility	Environmental/public concerns
1.Directly targeting *Musculista*			
Manual removal (scraping artificial surfaces, raking)	Potentially effective for *Musculista* control at small spatial scales*.	Feasible but thorough, systematic searching by divers required in order to be effective. Thus, a very slow and time-consuming method requiring on-going efforts.	Cleared areas may provide substrate for other pest species.
Wrapping/smothering of artificial structures and sediment	Likely to be effective against *Musculista* and other fouling organisms.	Only feasible for small spatial scales. Chemicals may be required to accelerate mortality. Labour intensive, but reduces the need for on-going dive surveys.	May be environmental concerns if chemicals (e.g. chlorine) are used to accelerate mortality. Likely to result in mortality of non-target organisms.
Biocontrol -enhancement of native predators	Requires understanding of native predators of *Musculista*. Likely efficacy remains unknown.	Practical application remains unknown.	May need to consider effects of predator on native species.
2. Habitat management			
Manage disturbances that influence competitors of Musculista (e.g. prevent disturbance to native macrophyte beds, reduce nutrient inputs, manage fisheries)	If integrity of native communities can be maintained or rehabilitated, may be effective in preventing spread and reducing abundance of *Musculista*.	May be feasible depending on disturbances involved and links with anthropogenic activity.	Minimal environmental concerns.
Rehabilitation of macrophyte beds	If dense macrophyte beds can be rehabilitated, reduced abundance of *Musculista* is likely.	Labour intensive and expensive to rehabilitate macrophyte beds on a large spatial scale*. *Musculista* mats may need to be thinned to increase chance of successful restoration.	Minimal environmental concerns.

*Small spatial scale = < 1000 m^2; large spatial scale = > 10 000 m^2.

Overall recommendations:

- It should be recognised that based on currently available information, for many jurisdictions application of the proposed decision support framework (Figure 4) is not likely to recommend management action(s) to control existing *Musculista* populations.
- With currently available technology, control options involving direct targeting of *Musculista* populations are extremely limited. Direct targeting of *Musculista* populations by hand removal (scraping or raking), dredging or smothering is only worth consideration in circumstances involving small (< 1000 m^2), isolated populations associated with high risk source nodes.
- The only potentially effective and publicly acceptable control method currently available for *Musculista* involves habitat management. Based on the limited impacts of *Musculista*, habitat management may not be justifiable in isolation due to the considerable costs involved. However, any broader strategy that aims to improve ecosystem health is likely to subsequently reduce abundance of *Musculista*.

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

Monitoring of *Musculista* is included in the National Monitoring Network (NMN), which is comprised of 18 locations across Australia[62]. Guidelines for monitoring *Sabella* within the NMN are included in the Marine Pest Monitoring Manual[63]. 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. Some jurisdictions may need to consider a range of additional monitoring, whereas for other regions, additional monitoring may be restricted to consideration of additional sites for detection of new incursions. Additional monitoring to be considered for the *Musculista* NCP (summarised in Table 2) comprises three 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[2, 64], only nine of the 18 NMN locations are of relevance to *Musculista* and three 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 *Musculista* from a high-risk source node to these high value areas. Any additional monitoring for *Musculista* should survey a range of habitats, given that it is capable of surviving in intertidal and subtidal habitats (to a depth of 20 m) and on soft or hard substrata[30].

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 *Musculista*. If an eradication attempt is initiated, monitoring will form a core component of the eradication program. Monitoring will involve quantifying *Musculista* 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 *Musculista* within a high value area, for example, estimating the abundance of *Musculista* 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 *Musculista* 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[30]:

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 *Musculista* 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. It would also be invaluable if NIMPIS includes results associated with control/eradication attempts.

Another potential data source lies with relevant government authorities. Approval of developments in the coastal zone may include biological surveys as part of environmental impact assessments. Information collected as part of these surveys could be relevant to *Musculista* and it is recommended that results from these surveys should also be incorporated into NIMPIS. 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 *Musculista*, but may also provide observations in relation to impacts. Where possible, state jurisdictions should engage industry to ensure collection of *Musculista* 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 *Musculista*.**

NCP Section & Monitoring objectives	**Additional monitoring locations**	**Nature of data**
1. Pest Prevention		
- To detect new incursions	Select additional sites based on transport pathways and environmental conditions at recipient locations	Presence/absence
- To detect new incursions in high value areas	Selected high value areas (e.g. aquaculture areas, Marine Protected Areas)	Presence/absence
2. Contingency Plan for new introductions		
- To determine spatial extent of new incursion and whether additional populations exist	Site of infestation along with adjacent suitable habitats	Presence/absence
- To assess the effectiveness of eradication attempts	Eradication site(s)	Abundance
3. Impact Management		
- To assess effectiveness of impact management strategies	Monitor in locations with/without impact management strategies.	Abundance; Monitoring of specific impacts (e.g. impacted industries or biota)
- To monitor the rate of spread	Various locations to establish the range of *Musculista*	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[65] and includes a variety of research areas that should contribute to improved management of marine pests (including *Musculista*) within Australia. The purpose of the R&D outlined in the *Musculista* 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 *Musculista* 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 *Musculista* spread, it is particularly important that an assessment of the likely efficacy of the proposed guidelines be conducted (Table 3; PP1). To enhance the efficiency of the ballast water decision system (DSS) that underpins ballast water management, improved understanding of life-stage specific data is required for *Musculista*, particularly in relation to temperature tolerance (Table 2; PP2). This information plays an important role in determining whether a vessel will become infected with *Musculista* during ballast uptake, and whether or not it will complete its life-cycle in a recipient port[64].

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[66]. Development and/or testing of innovative tools to eradicate and/or control *Musculista* 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). As part of this research area, it is recommended that the efficacy of wrapping/encapsulation methodologies[37, 56] be tested for their efficacy against *Musculista*. Understanding the likely capacity for natural *Musculista* spread is another key research question that has significant implications for managers (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. An understanding of the reproductive ecology of *Musculista* in Australian environments is also considered to be a priority research area (Table 3; CP3). This knowledge should benefit the

decision-making process involved in emergency response plans, since it is important that eradication attempts are undertaken before *Musculista* spawning occurs. Improved understanding of the reproductive ecology of *Musculista* will also inform potential actions outlined in the pest prevention and impact management sections of the NCP. A final priority research area involves clarifying the taxonomic status of temperate and tropical strains of *Musculista* (Table 3; CP4). Uncertainty in this area recently proved to be impede the decision-making process with a suspected new incursion (A. Leedman, DEWHA, pers. comm., April 2008).

Impact management

Assessing the economic and environmental impact of *Musculista* is a vital component of the NCP because it plays a pivotal role in determining whether or not control actions should be pursued (see Figure 4). While economic impacts are presently considered minimal, the environmental impacts of *Musculista* are poorly known in Australian environments and should be the subject of future research efforts (Table 3; IM1). Understanding impacts of *Musculista* is potentially complex and may differ depending on the region concerned so it is important that environmental impacts are assessed across a range of spatial scales.

Understanding the invasion process, particularly the importance of human-mediated disturbance, is a fundamental stage in assessing impact and prioritising management activities (Table 2; IM2). If *Musculista* 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 claimed that in both its native and invaded range high density *Musculista* mats are only present in degraded habitats[7]. If disturbance plays a similar role in the invasion process in Australia, the threat posed by *Musculista* would be considered minimal in which case management funds would be best allocated to more threatening species or processes. Understanding the role of native predators in conferring resistance to invasion is also recommended as a key research area that may lead to an increased range of control options (Table 2; IM2). 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[67].

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 *(Relevant decision support framework)*	Relative importance to NCP	Cost effectiveness (indicative costs $'000)	Technical Feasibility	Priority score	Relative priority
Pest Prevention	PP1. How effective are the aquaculture best practice guidelines for biofouling in reducing translocation risk? *(Figure 2)*	4	4 (75)	4	12	**4**
	PP2. Improved understanding of life-stage specific data. *(Figure 2)*	4	4 (75)	4	12	**4**
Contingency Plan for new introductions	CP1. Development and testing of novel eradication/control tools *(Figures 3, 4)*	5	2 (200)	1	8	**2**
	CP2. What is the likely capacity for natural *Musculista* spread? *(Figures 1, 3)*	5	3 (100)	2	10	**3**
	CP3. Improved understanding of *Musculista* reproductive ecology? *(Figures 2, 3, 4)*	5	3 (100)	4	12	**4**
	CP4. Clarify taxonomic uncertainty surrounding temperate and tropical *Musculista* strains? *(Figures 2, 3, 4)*	5	4 (50)	4	13	**5**
Impact management	IM1. What are the environmental impacts of *Musculista*? *(Figure 4)*	5	2 (200)	3	10	**3**
	IM2. Improved understanding of invasion process, including the role of disturbance in establishment and maintenance of *Musculista* populations and the role of native predators in conferring invasion resistance? (*Figure 4*)	4	2 (200)	4	10	**3**

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 *Musculista* NCP. For example public awareness and education strategies aimed at reducing the spread of marine pests through management of biofouling will be applicable to *Musculista*. Additional strategies which should be considered to enhance the effectiveness of the *Musculista* NCP include:

Additional strategies – Pest prevention

Additional public awareness strategies may include targeted public awareness campaigns directed at high risk nodes where *Musculista* 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 activities and dredging probably represent the greatest risk for translocation of *Musculista*. If additional public awareness strategies are developed, it is vital that stakeholders from these sectors are targeted.

Additional strategies – Contingency plan for new introductions

Early detection of new incursions of marine pests is a critical factor in the success of eradication programs and the public can play a key role in this regard. For *Musculista*, the role of the public in detecting new incursions is limited, because mytillids such as *Musculista* are notoriously difficult to identify. Notwithstanding this issue, careful observation by those familiar with local marine systems could still result in early detection of a *Musculista* incursion, providing that the species identity is confirmed by an appropriate expert.

As part of a public awareness strategy for *Musculista*, it is important that information regarding current distribution patterns and likely natural spread is publicly available, 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 what constitutes a 'significant range extension' for *Musculista* so the public can be properly educated/informed.

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

With regard to new *Musculista* incursions, public awareness strategies in relation to emergency response are covered in the Australian Emergency Marine Pest Plan[42] (EMPPlan).

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 *Musculista*, 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. manual 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 habitat (e.g. intertidal versus subtidal).

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 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 localised reduction of *Musculista* densities associated with a high risk 'source' node. Wrapping of artificial structures and smothering of sediment with plastic is proposed as an impact management methodology because it is considered to be potentially effective against *Musculista* on both types of substrate (see section F). It should be noted that further testing of the method is required to determine its effectiveness as a control method against *Musculista*. To provide a realistic budget, impact management activities are based upon targeting a *Musculista* infestation associated with a small coastal wharf, comprising 200 wharf piles and approximately 10 000 m^2 of seafloor. These dimensions closely match the size of a New Zealand wharf that was recently the subject of control efforts against a fouling invertebrate pest[68].

The costs involved in habitat management were not included in the indicative budget for a number of reasons. Firstly, there is a significant level of uncertainty associated with cost estimates for habitat management (e.g. reducing nutrient input, fisheries management) and the capacity to implement such management depends on the jurisdiction concerned. Secondly, including habitat management within a *Musculista* budget is not considered appropriate, because it is unlikely that habitat management would be the carried out for the sole purpose of controlling *Musculista* populations (as discussed in section F).

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 *Musculista* National Control Plan (as at January 2008).**

NCP section	Budget items	Likely Costs ($AUD)	Funding arrangements/ expected financier
Pest prevention	No applicable budget items	NA	**NA**
Contingency plan for new introductions	Eradication of new incursion (including on-going monitoring)	$860 000 – 263 million per incursion[2]	Interim cost-sharing arrangements are in place
Impact management	Case study example. Wrapping of wharf piles and smothering of benthos beneath wharf[a]. Wharf piles[b]: Labour - including application & removal ($35 000), materials ($3830) Benthos[b]: Labour - including application & removal ($26 200), materials ($5500)	$70 530 per year	State/territory governments
	Habitat management (e.g. manage anthropogenic inputs, rehabilitation of macrophyte beds)	Uncertain	State/territory governments
Monitoring	Additional monitoring sites to detect new incursions. -Requirement for additional monitoring sites will depend on jurisdiction and vectors operating.	$10 000- $20 000[c] per site per year	State/territory governments
	Monitoring to evaluate effectiveness of impact management strategy e.g. Quarterly monitoring of wharf piles and benthos[d] Labour ($24 000[e]), Boat hire ($6000[f]), Car hire ($1200[g]), Tank fills ($1152[h]), Consumables ($500[i]), Data analysis and write-up ($30 000[j])	$62 852 per year	To be advised
	Monitoring rate of spread	$10 000 per year	To be advised
R&D	Various R&D areas (see Table 3)	$1 million[k] over 3 years	Commonwealth & state/territory governments
Communications strategy	Depends on the impact management measures implemented	Uncertain	State/territory governments
Overall co-ordination	Salary for project officer (0.5 FTE)	$50 000 per year	To be advised

[a] Based upon treatment of small coastal wharf comprising 200 wharf piles and 10 000 m^2 of seafloor; [b] For details on cost estimates refer to Coutts (2006)[56] and Pannell and Coutts (2007)[68]; [c] Cost effectiveness could be improved by surveying multiple pest species; [d] Based on surveys of wharf piles and benthos, 3 days/quarter, (1 x 4 person dive team), total of 12 days; [e] Divers cost $500/day (salary plus per diem), based on 4 person dive team & 3 field days/quarter; [f] Boat hire $500/day; [g] Car hire $100/day; [h] Tank fills based on 36 fills/month @ $8 per fill; [i] Consumables including waterproof paper, slates, stationary; [j] Data analysis and write-up by suitably qualified scientist; [k] Assumes all priority R&D areas are addressed.

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 *Musculista* 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).**

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

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[30] http://crimp.marine.csiro.au/nimpis
- The Web-Based Rapid Response Toolbox[43] http://crimp.marine.csiro.au/NIMPIS/controls.htm.
- Pre-Developing Technology for Marine Pest Emergency Eradication Response[44] (in review)
- Rapid Response Manual – *Perna/Mytilopsis* (under development)
- Rapid Response Manual – Generic (under development)
- Australian Emergency Marine Pest Plan[42] (EMPPlan)
- National System Marine Pest Identification Card – *Musculista senhousia* (under development)

Monitoring

- Australian Marine Pest Monitoring Guidelines: Version 1 (December 2006)[62]
- Marine Pest Monitoring Manual: Version 1 (December 2006)[63]