An Australian Government Initiative

NATIONAL CONTROL PLAN

Japanese seaweed or wakame

Undaria pinnatifida

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 Japanese seaweed or wakame *Undaria pinnatifida*

Prepared for the Australian Government
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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 Japanese seaweed *Undaria pinnatifida*.

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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 *Undaria pinnatifida*, 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 *Undaria pinnatifida* (hereafter referred to as *Undaria*) 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 *Undaria* within Australian environments.
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The overarching decision support framework for *Undaria* 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 *Undaria*, 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.

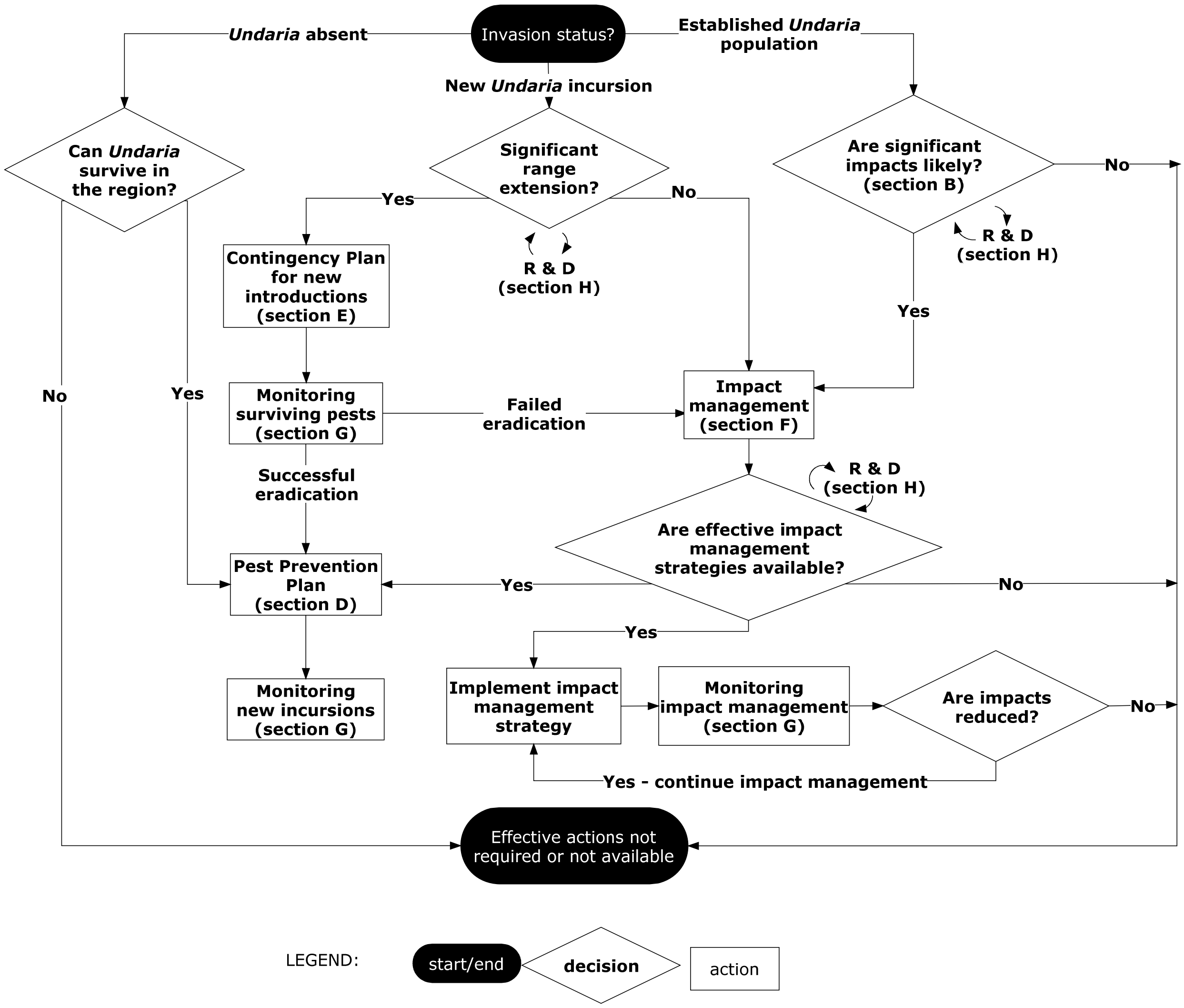

Figure 1. **Overarching decision support framework for *Undaria* management. There is inherent uncertainty associated with some questions (e.g. Can *Undaria* survive in the region?) so decisions must be made on the best available information (e.g. species range mapping data[2]). Note that if effective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

Economy:

Impacts in native and invaded ranges

Undaria does not have any documented negative economic impacts in its native range. It forms the basis of a large aquaculture and commercial fishery that produces over 240 000 tonnes (wet weight) per year in Japan[5] and Korea[6] alone.

In its invaded range, there have been few reports of *Undaria* associated economic impacts due to fouling of marine structures or aquaculture operations, although anecdotal evidence suggests otherwise[7]. In New Zealand, *Undaria* causes nuisance fouling, but it is generally perceived to be of minimal concern and is just one of a number of fouling species[8]. Evidence of fouling related costs have not yet been reported and are considered unlikely in the future, given that *Undaria* has been present in some parts of New Zealand since at least 1987[8]. Proposed treatment of aquaculture seedstock and equipment to prevent translocation of *Undaria*[9] could lead to increased labour costs, although these are yet to be quantified.

The potential impacts of *Undaria* invasion on fisheries have been considered in New Zealand, however, at this stage there is no evidence of negative impacts[8]. There has been particular concern associated with potential impacts of *Undaria* on the valuable 'paua' (*Haliotis iris*) fishery, but predictions of both positive and negative impacts have been made[8]. Conflicting predictions are believed to be due to the complex interactions between *Undaria* and paua and will only be resolved with robust scientific research[8].

In Argentina, it has been speculated that invasion of commercially important *Gracilaria gracilis* could lead to reduced productivity of this seaweed resource fishery[10]. While *Undaria* has recently been found in populations of the *Gracilaria gracilis*, negative impacts on production are yet to be reported.

Impacts in Australia

Negative economic impacts attributable to *Undaria* have not been reported in Australia (refer to NIMPIS[59] for details on *Undaria* distribution). Fouling of marine structures or aquaculture operations is the most likely source of economic impact. If *Undaria* is capable of displacing native species, there may be flow-on effects to fisheries, particularly if the productivity of seaweed beds is reduced following *Undaria* invasion. Under these circumstances, the productivity of commercial fisheries that depend on seaweed beds as a source of food (e.g. abalone, rock lobster) could potentially be reduced.

Commercial harvest of *Undaria* has resulted in some positive economic impacts, with Marinova Pty Ltd processing approximately 200 tonnes of *Undaria* per year from Tasmanian waters for food and neutraceutical products[11].

Environment:

Impacts in native and invaded ranges

There are no reported environmental impacts of *Undaria* in its native range. From the limited number of studies that have examined impacts of *Undaria* in its invaded range, the extent of impact appears to vary depending on the country and region concerned. Local environmental characteristics, particularly wave exposure, may also influence the likely distribution and impact of *Undaria*[12].

Studies in Italy[13] and Argentina[10] have shown that *Undaria* competes with indigenous seaweeds for space, resulting in reduced species richness and diversity of native seaweeds. Changes in understorey composition as a result of *Undaria* invasion in New Zealand have been inferred by comparing assemblages between *Undaria* beds and native seaweed (*Carpophyllum* spp.) beds[14]. While this may appear to indicate significant impacts, this study did not include observations made before the *Carpophyllum* were invaded by *Undaria*. Consequently, it is equally possible that the distribution of understorey species reflected environmental factors unrelated to the presence or absence of *Undaria*. Casual observations made before and after *Undaria* invasion have noted significant changes in understorey composition following *Undaria* invasion, however, these are not supported by quantitative data[12].

Other experimental work conducted in New Zealand does not provide any evidence of displacement of native species by *Undaria*[15]. It should be noted that this study was conducted in a sheltered harbour where a low frequency and intensity of disturbance may have allowed *Undaria* to establish only as localised patches within an otherwise homogenous canopy of indigenous species.

Undaria is a relatively recent arrival in North America and its impacts remain largely unknown. Grazing by herbivores, predominately the native kelp crab *Pugettia producta*, have been shown to limit effective recruitment of *Undaria*[16].

The ultimate assessment of impacts on native communities depends upon the ability of *Undaria* populations to displace native algal communities. Experimental studies in New Zealand and France have shown that stable native canopies are resistant to *Undaria* invasion[17, 18]. However, when native algal canopy cover is reduced experimentally (mimicking disturbances such as sea urchin grazing or storm damage), *Undaria* successfully establishes. The scale of disturbance also appears to influence the ability of *Undaria* to persist, with increasing levels of persistence evident in larger scale disturbances[18].

Impacts in Australia

Disturbance plays an important role in the invasion ecology of *Undaria* in Tasmania. Removal of native algal canopies, either experimentally[19, 20], or via destructive sea urchin grazing[21] results in the formation of dense stands of *Undaria*. In the absence of disturbance, native canopies are resistant to *Undaria* invasion. As in New Zealand, the scale of disturbance influences the ability of *Undaria* stands to persist in Tasmania. Recovery of native canopies in small scale experimental disturbances occurred within 18 months, however, in larger scale disturbances caused by urchin grazing, no recovery was evident following 30 months of urchin removals.

If the observed response of *Undaria* in Tasmania is a general phenomenon, the abundance and subsequent impacts of *Undaria* will be dependent on the frequency and intensity of disturbance. The timing of disturbance will also have an effect. Disturbances just prior to development of *Undaria* sporophytes are likely to result in formation of dense *Undaria* populations[20].

Since *Undaria* appears reliant on disturbance to facilitate invasion it is less threatening to the integrity of native communities than if it was capable of establishment in the absence of disturbance. However, persistence of *Undaria* dominated communities has been observed in the absence of continued disturbance for large scale incursions. Positive feedback mechanisms can maintain *Undaria* dominance once it is established[21]. Under these circumstances, long-term impacts of *Undaria* are likely.

It should also be recognised that impacts on native communities are still conceivable as a result of opportunistic establishment of *Undaria*. For example, many native algal species have seasonal or infrequent recruitment windows so even short-lived *Undaria* incursions could have long-term effects on macroalgal community composition. The impact of competition between *Undaria* and threatened species (e.g. Giant kelp *Macrocystsis pyrifera*) also remain unknown.

Other potential impacts of *Undaria* that remain poorly understood include effects on nutrient cycling and trophic dynamics. A small scale correlative study conducted on the east coast of Tasmania indicates that such impacts are likely, with observations of reduced diversity and abundance of fauna associated with a canopy of *Undaria* compared with an adjacent canopy of indigenous species[22].

Human health & Amenity

There are no reported or anticipated impacts of *Undaria* on human health. *Undaria* may have negative impacts on public amenity. The ability of the plant to form dense populations in intertidal and subtidal areas may reduce the value of these natural habitats. Sheltered rocky reefs and intertidal platforms are particularly popular with divers, fishermen and shore fossickers and these groups are likely to be most affected.

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 *Undaria* was finalised in 2006[23]. The business case summarises the likely threat and impacts of *Undaria* 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 *Undaria*, 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 Undaria

Undaria 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:

Undaria overgrows and excludes native species causing nuisance fouling of vessels and marine structures, and loss of aquaculture, recreational and commercial harvest. It dominates and out-competes native species and alters natural biogeochemical cycles. It is present in three out of 60 Australian marine bioregions (as defined in the Interim Marine and Coastal Bioregionalisation for Australia – IMCRA[24]).

Potential for further introductions and spread of the six species

Undaria 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). *Undaria* 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.

Undaria 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 *Undaria* to establish pest populations. On the basis of water temperature it has the potential to invade 50 bioregions (currently present in three).

Benefits of National Control Plans

NIMPCG considers that the implementation of a NCP for *Undaria* 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 *Undaria* 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 *Undaria*, the benefit to cost ratio was 0.2 where eradication of the species was not considered possible and 0.9 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 *Undaria*, including existing arrangements, is shown in Figure 2. Reducing the risk of ballast water – mediated translocation of *Undaria* 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. *Undaria* has been nominated as one of the species for which ballast water management between Australian ports will be required.

Biofouling:
Undaria has a propensity to attach to floating structures[25] and can be transferred via biofouling. National best practice management guidelines for management of biofouling are currently being developed for various marine sectors[26] including domestic recreational vessels, aquaculture, commercial fishing and petroleum industries. Adherence to these guidelines should ensure that translocation risk is reduced.

The main vector for both inter and intra-regional spread of *Undaria* to new locations has been via fouling of ships' hulls[25]. It is particularly important that measures are taken to reduce the risk of spread via this vector. While the aforementioned biofouling guidelines are currently under development, a range of potential protocols are available to reduce translocation risk. Potential protocols include: 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; and inspecting and cleaning equipment and areas which may accumulate mud, sediments and/or fouling organisms, including dredge fittings, anchor cables and lockers, buoys, floats and booms and similar equipment.

Another vector of known significance in relation to translocation of *Undaria* is movement of equipment and seedstock associated with aquaculture activities[27, 28]. National best practice guidelines are also currently under development for this sector. A range of techniques are available[9] for removal of *Undaria* from equipment and seedstock, including a number of simple and environmentally friendly methods (e.g. air drying, freshwater immersion).

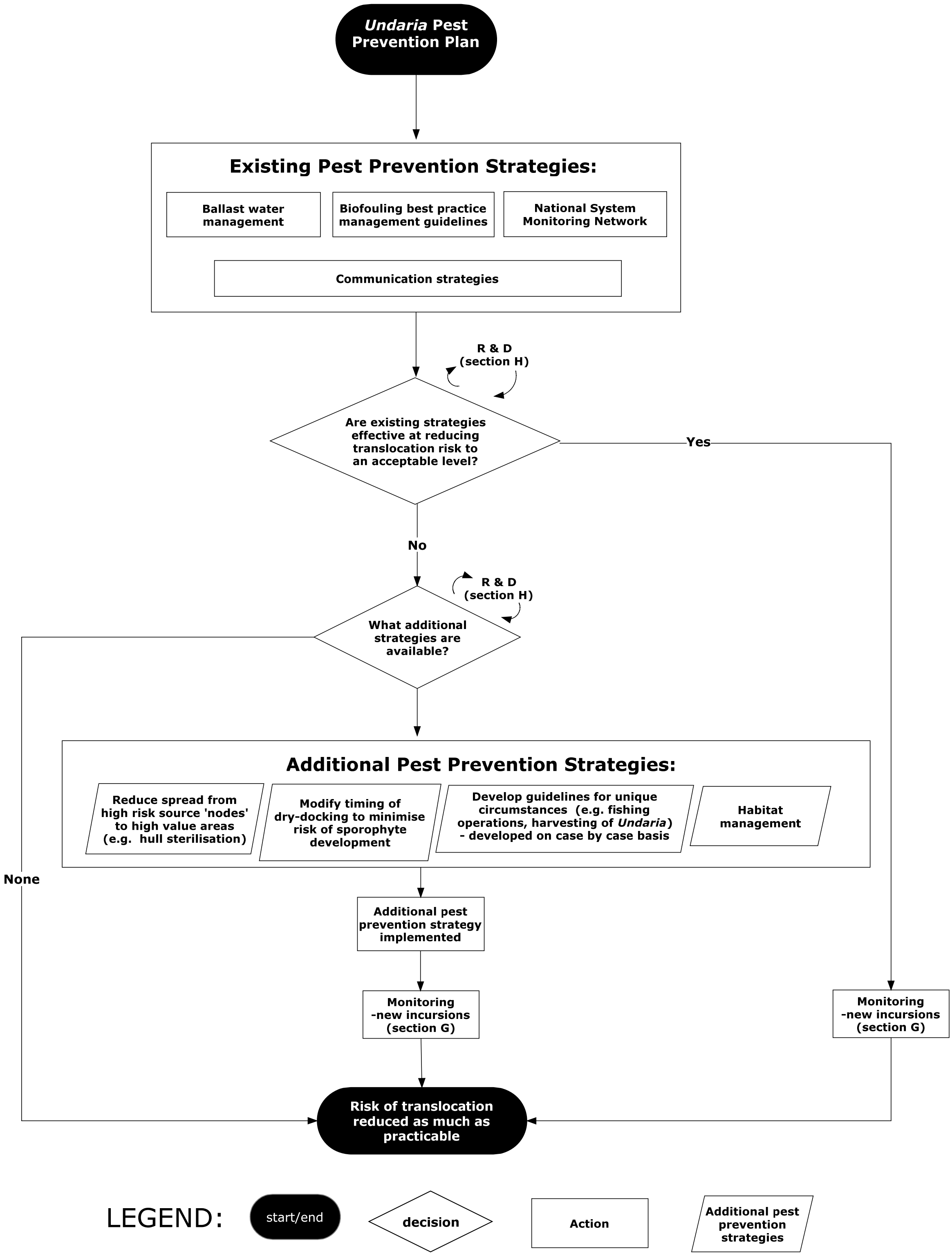

Figure 2. Pest prevention plan and decision support framework applicable to *Undaria*.

Additional Pest Prevention Strategies:

- Transfer of *Undaria* 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 because even well maintained vessels can be vectors for marine pests. 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[29]). Similarly, divers operating in *Undaria* infested locations should be encouraged to thoroughly wash (using freshwater and/or detergent solution) and dry gear to minimise translocation risk. To encourage up-take of these practices, effective public awareness and communication campaigns will be an integral component of the strategy.
- Similarly, timing of dry-docking/application of antifouling may also be considered as an additional means of reducing the risk of *Undaria* fouling[30]. If a vessel is removed from the water once the period of spore release has concluded the risk of *Undaria* sporophytes developing on the hull in the subsequent growth season will be reduced significantly.
- 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[31]. Fishermen 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 has been caught in their fishing gear (e.g. non-draining bins). Similar protocols may need to be developed if there is a risk of *Undaria* entrainment and translocation associated with fishing or related activities.
- If harvesting of *Undaria* is permitted for commercial purposes, it is vital that appropriate guidelines are provided to ensure that harvesting activities do not result in further spread of the plant. Given the strong likelihood that *Undaria* would become entrained in collection gear (e.g. dive gear, bilges, anchor wells), the guidelines for commercial harvesters may need to be more stringent than general guidelines proposed for commercial fishing operators.
- Given that stable native canopies provide resistance to *Undaria* invasion[17, 19, 20], habitat management should also be considered as part of an integrated strategy to prevent further *Undaria* spread. Where human activity can be linked to loss of native canopy algae, indirect control options to prevent further spread may exist by focusing efforts to minimise anthropogenic disturbances[32]. For example, maintaining the integrity of populations of sea urchin predators may indirectly prevent further *Undaria* spread, by preventing increases in sea urchin population density and subsequent overgrazing of native algae.

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 of *Undaria* is provided in Figure 3. The decision on a national response to eradicate new introductions or range extensions of *Undaria* 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)[33].

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 *Undaria* incursions. The National Introduced Marine Pest Information System NIMPIS rapid response toolbox[34] 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[35]. 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[36].

The range of treatment options available for a marine pest emergency involving *Undaria* 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 *Undaria* incursion is to detect it early and eradicate or contain the population before further spread occurs.

One of the key challenges associated with eradication of *Undaria* populations involves the microscopic gametophyte stage which is particularly difficult to detect and eradicate. Where possible, eradication efforts should proceed before *Undaria* plants become fertile. If this is not achievable, options available to eliminate the gametophyte stage are extremely limited. Heat treatment is a potentially effective method[37], but requires further development to be useful for large treatment areas and complex reefs (see sections F, H).

A critical question for managers when responding to new *Undaria* 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 is the interaction between larval life history and local environment[38]. *Undaria* can disperse via a number of mechanisms including (1) microscopic spores; and (2) adult plants either drifting or attached to unstable substrata. Dispersal via spores[39] is typically in the order of 10^1 m, while larger scale dispersal in the order of 10^3-10^4 m can be achieved by drift plants[39]. The size of the source population and the strength of local currents can also influence the capacity for natural spread[39]. Observations in Tasmania suggest that natural spread can be up to 10 km a year, but is usually less than 5 km[30]. Thus, spread greater than 20 km per year could probably be expected to be unlikely to be due to natural means, unless it was associated with a strong tidal flow.

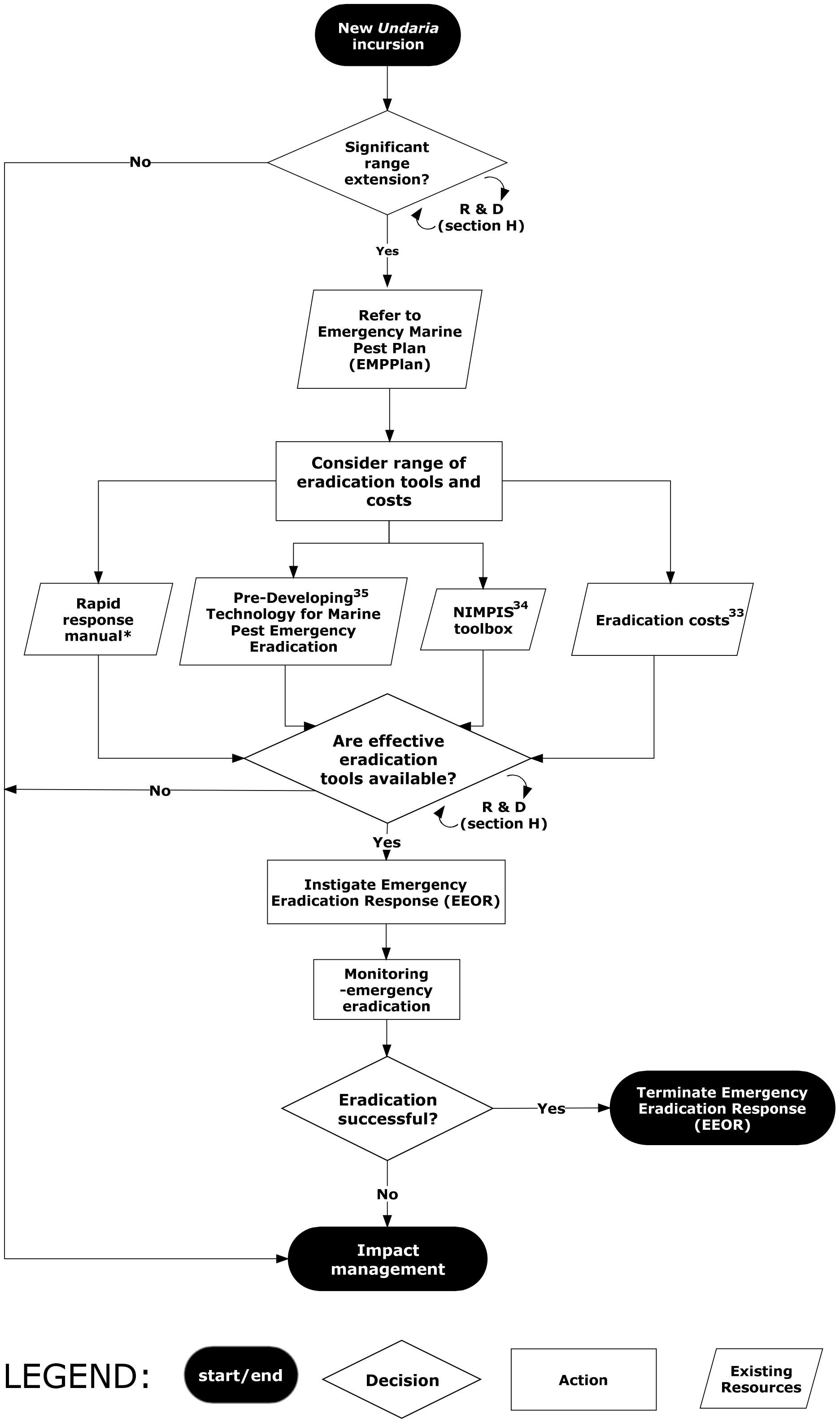

Figure 3. **Decision support framework for new introductions of *Undaria* highlighting the currently available resources to assist the decision-making process. *Resources currently under development.**

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 *Undaria* impact management is outlined in Figure 4. It is not appropriate to assign *Undaria* 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, for most jurisdictions impact of *Undaria* is likely to be in the 'low-moderate' category for both economic and environmental impact based upon the threat analysis (section B) and the scheme proposed in Figure 4. In economic terms, the main impacts are likely to relate to nuisance fouling (indicator of 'moderate' management priority) and potential lost productivity of aquaculture operations (indicator of 'low' management priority). In terms of environmental impacts, while it appears that *Undaria* 'tracks' ecosystem dynamics (indicator of 'low' management priority), it is likely that its presence may influence rehabilitation of native species as well as influencing key resources (indicator of 'moderate' management priority).

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 associated costs involved. To justify investment in on-going management, it is essential that likely benefits exceed 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)[24]' 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 *Undaria*; (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. Seasonality is a particularly important issue in relation to *Undaria* management, because it is an annual species that alternates between a macroscopic sporophyte and a microscopic gametophyte. In some areas the macroscopic sporophyte is present all year round, but the sporophyte typically displays a strong seasonal growth pattern and the timing is dependent upon water temperature. In Tasmania, the sporophyte appears in winter and in warmer waters, reach maximum size in spring before senescing by the end of summer[40]. To maximise the effectiveness of management activities, control efforts should sensibly target the macroscopic sporophyte prior to development of reproductive tissue (sporophylls).

(1) Direct targeting of Undaria:

<u>Physical removal</u>

Physical removal is the only impact management option currently available that is potentially effective in reducing *Undaria* sporophyte abundance[7, 41]. Removal of *Undaria* from a small-scale (800 m^2) experimental area reduced sporophyte abundance in a Tasmanian study, however, persistence of 'hot spots' through time suggested that microscopic stages create a 'seed bank' that persist for longer than two and a half years or that selective gametophyte survival in microhabitats occurs[7]. Hewitt et al.[7] suggest that in order for manual removal of *Undaria* to be an effective control option a long-term commitment to removal needs to be combined with vector management and education initiatives to reduce the chances of re-inoculation and spread, with monitoring on a larger spatial scale for the early detection of other incursion sites. A treatment to remove persistent microscopic stages is also suggested to be a valuable tool to remove microscopic stages. Heat treatment has been successfully used to eliminate gametophytes from the hull of a sunken ship[37] and has potential for treatment of natural reefs. An *in-situ* steam sterilisation unit has been recently trialled by Golder Kingett Mitchell Ltd following commissioning by MAF Biosecurity New Zealand. While the technology holds promise, the total treatable area by a single team of divers over one working day at depths of up to 10 m is very small (approximately 6 m^2). The tool is also unsuitable for effective treatment of substrate within narrow rock fissures, confined overhangs, or closely grouped boulders, so further development is required before it can be considered of widespread appeal as an eradication option (see section H). The final report describing this research has not been officially released at the time of writing. MAF Biosecurity New Zealand kindly provided an unpublished progress report for discussion within the NCP.

Physical removal as part of commercial harvest of *Undaria* is another potential option for reducing impacts. In Tasmania, approximately 200 tonnes of *Undaria* is harvested annually[11]. Commercial harvesting does not appear to have reduced spread of the plant, although the impact of harvesting on patterns of spread and abundance remains poorly understood (A. Morton, Tasmanian Department of Primary Industries and Water, pers. comm., Jan 2008). Given the lack of success in small-scale removals it is probable that harvesting leads to only short-term reductions in *Undaria* sporophyte abundance. It is also unlikely that commercial operators would jeopardise the sustainability of the resource by removing all plants. Furthermore, when harvested for commercial purposes in France, in general only large thalli of healthy appearance are selected[34]. Critical evaluation of the effectiveness of commercial harvesting as a control option is required, including an understanding of the impacts of *Undaria* harvesting activities on native floral and faunal communities, before it can be considered a serious option for reducing *Undaria* impacts.

<u>Biological control</u>

Biological control has been considered as a management option for other introduced species (e.g. *Carcinus maenas*[42], *Asterias amurensis*[43]), however, further research is required before it could be considered a serious control option against *Undaria*. Genetic manipulation of pest species is another option that 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[44]. 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. Even if the efficacy of genetic modification could be demonstrated, 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

A range of chemicals are potentially effective against *Undaria*[34], however, they are only likely to come under consideration in circumstances where the population is contained (e.g. marinas). For established *Undaria* populations in open systems, such as those that have been observed in Australia, 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.

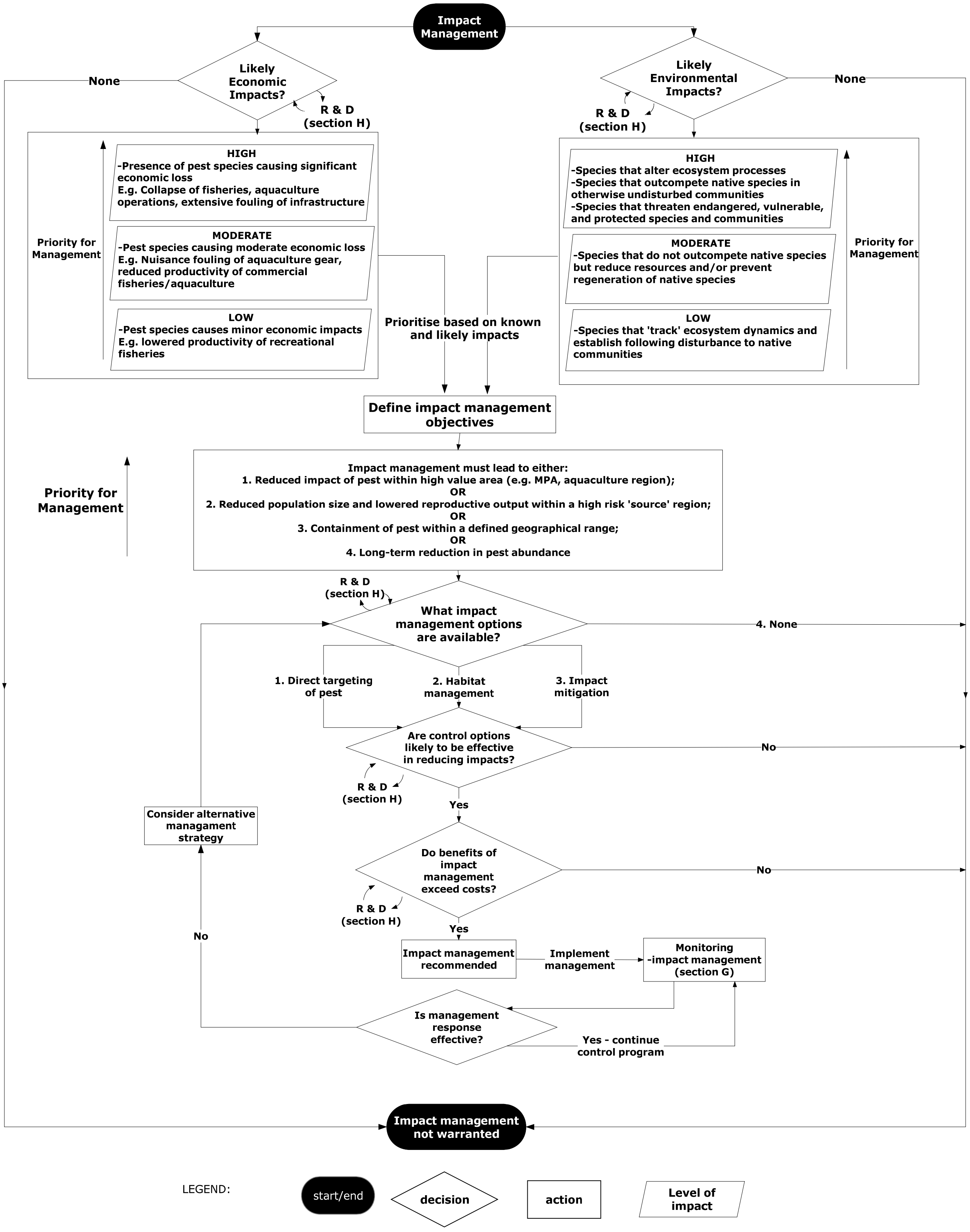

Figure 4. **Impact management decision support framework applicable to *Undaria***

(2) Habitat management:
The demonstrated links between invasion success and disturbance provides potential control options for *Undaria*. 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 plant. Some disturbances to native seaweed beds are beyond the scope of control (e.g. storm damage), however, a number of human-mediated disturbances can lead to loss of native algal cover including sedimentation[45], pollution[46] and sea urchin grazing[47-51].

In Tasmania, destructive grazing by sea urchins (*Heliocidaris erythrogramma*) is the most likely source of disturbance to native algal beds. Recent work in Tasmania has indicated that the spiny lobster *Jasus edwardsii* is a significant predator of *H. erythrogramma* and that reduced abundances of lobsters as a result of fishing activity is sufficient to account for barren formation[52]. Managing lobster populations to maintain sea urchins at low levels, therefore, provides a potential option for control of *Undaria*. It should be emphasised that the time frame for recovery of the native algal canopy may require several decades. For example, the transition from urchin barren to kelp on New Zealand reefs occurred over a 20-year period following reduced fishing pressure after declaration of a marine reserve[53].

Another potentially complementary habitat management approach involves increasing the rate of native algal recovery by transplanting reproductive adults or juvenile plants[54, 55]. While this approach has been demonstrated to be effective at small scales, its practicality and effectiveness on a large scale remains unknown. Furthermore, it should only be considered as part of an integrated strategy that also includes management actions that target the cause of the loss of native algal canopy in the first place.

It should also be recognised that recovery of native algae is a potentially complex process and in some circumstances positive feedback mechanisms may also act to prevent re-establishment of native algae. Therefore, while habitat management may prevent expansion of *Undaria* populations, whether or not habitat management can be used to convert established *Undaria* beds back to seaweed beds dominated by native algae remains speculative. For example, poor recovery of native algae in a Tasmanian study[21] was observed following experimental removal of sea urchins and *Undaria*, even when combined with an enhanced supply of native algal spores. This lack of recovery is thought to be due to a build up of sediment on the substrate that occurred following loss of the native algal canopy.

(3) Impact mitigation:
The lack of reported economic impacts attributable to *Undaria* invasion has so far precluded development of impact mitigation strategies. If fouling of aquaculture equipment becomes an issue for the aquaculture sector, a number of impact mitigation strategies could be considered. For example, periodic removal of equipment from the water for cleaning and treatment (e.g. air drying, water blasting[9]) is likely to reduce levels of *Undaria* fouling. Similarly, deployment of aquaculture equipment during periods when *Undaria* spore abundance in the water column is low may also be considered as a potential means of limiting the development of *Undaria* fouling (see Sanderson 1997[30]).

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

Method	Likely Efficacy	Feasibility	Environmental/public concerns
1.Directly targeting *Undaria*			
Physical removal of sporophytes	Effective in reducing sporophyte population density.	Practical only for small spatial scales*. On-going removals required.	Disturbance of benthos by divers may lead to further *Undaria* spread.
Heat treatment of benthos	Potentially effective in eliminating microscopic life history stages.	Only feasible at small spatial scales*. Also limitations with respect to treatment of high complexity reef (e.g. cracks, crevices).	Will also eliminate microscopic stages of native organisms.
2. Habitat management			
Maintain integrity of native seaweed beds	Potentially effective in preventing expansion of existing *Undaria* beds.	Effective if there are clear links between human-mediated disturbance and integrity of native seaweed beds.	Minimal environmental concerns.
Promote recovery of native seaweed beds via management of sea urchin predator populations	Efficacy remains to be proven for control of *Undaria* at large spatial scales.	Feasible but may require long time period before positive changes observed (e.g. Babcock 1999). No recovery was observed following 2.5 years of experimental manipulations [21.]	Requires a ‘system’ level approach to fisheries management.
Kelp bed rehabilitation	Potentially effective method of increasing rate of native algal recovery, but only if part of a broader strategy that also addresses the factors contributing to the initial loss of kelp beds.	Practicality on a large spatial scale* remains to be demonstrated.	Minimal environmental concerns.
3. Impact Mitigation			
-*Modify aquaculture practices* (e.g. retrieval and treatment of equipment, managing timing of equipment deployment).	May be effective if there is a clear seasonality in pattern of spore release.	Feasible but there will be high labour costs incurred to industry.	Minimal environmental concerns.

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

Overall recommendations:

- If practical, impact management strategies should focus on reducing *Undaria* abundance and/or impact mitigation in high value areas (e.g. aquaculture regions, MPAs, regions where threatened species or communities are present).
- Physical removal of *Undaria* populations remains the only potentially effective control method for reducing sporophyte abundance and subsequent reproductive success. However, this method is very labour intensive and only likely to be practical for small-scale (< 1000 m^2) populations.
- Where invasion success can be linked to human activity, managing the human-mediated activities represents an indirect method of controlling *Undaria* and may be more cost-effective than targeting the plants directly.

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

Monitoring of *Undaria* is included in the National Monitoring Network (NMN), which is comprised of 18 locations across Australia[56]. Guidelines for monitoring *Undaria* within the NMN are included in the Marine Pest Monitoring Manual[57]. The primary objectives of the NMN 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 *Undaria* 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, 58], only nine of the 18 NMN locations are of relevance to *Undaria* and two of these locations already have established populations. Consequently, additional monitoring sites should be considered by local jurisdictions on a case-by-case basis, taking into account 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 *Undaria* from a high risk source node to these high value areas. Since *Undaria* can establish from the intertidal zone to a depth of at least 15 m, diving surveys are necessary for detailed monitoring programs. Due to the propensity of *Undaria* to attach to artificial structures, a low cost regular monitoring program could be carried out by surveying artificial structures from the surface at low tide[8]. Seasonality is a particularly important issue in relation to *Undaria* monitoring, because it is an annual species and alternates between a macroscopic sporophyte and a microscopic gametophyte (see section F). Since the ability to detect *Undaria* is reliant on observations of the sporophyte, it is important that seasonality is taken into account when designing additional monitoring strategies.

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 *Undaria*. If an eradication attempt is initiated, monitoring will form a core component of the eradication program. Monitoring will involve quantifying *Undaria* 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 *Undaria* within a high value area, for example, estimating the abundance of *Undaria* 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. For example, if management activities focus on an area with high 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 *Undaria* 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[59]:

In many states there are government-funded programs in place involving monitoring of marine communities (e.g. 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 *Undaria* 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. Community-based organisations may also be involved with monitoring of marine pests. Monitoring *Undaria* is particularly relevant to community based surveys, because it occurs on intertidal and subtidal rocky reef communities and is a large conspicuous species that is easily identified by divers with a basic level of training. Community organisations such as 'Reefwatch' in South Australia are already actively involved in monitoring pests such as *Undaria*.

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 *Undaria* 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 *Undaria*, but may also provide observations in relation to impacts. Where possible, state jurisdictions should engage industry to ensure collection of *Undaria* 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 *Undaria*.

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 *Undaria*	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 (R&D) has been completed[60] and includes a variety of research areas that should contribute to improved management of marine pests (including *Undaria*) within Australia. The purpose of the R&D outlined in the *Undaria* 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 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 *Undaria* 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 hull fouling and aquaculture activities as a vector for *Undaria* spread, it is particularly important that an assessment of the likely efficacy of the proposed guidelines be conducted (Table 3; PP1). The efficacy of in-water hull sterilisation as a means of preventing translocation of *Undaria* to high value areas is also recommended as an important research area (Table 3; PP2).

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[61]. Development of innovative tools to eradicate *Undaria* 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). The presence of microscopic life history stages presents particular difficulties in relation to detection and eradication of new *Undaria* incursions and it is essential that prospective treatments are effective against microscopic *Undaria* life-history stages. Further development of *in-situ* methods for application of heat treatment is recommended as part of this research.

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 biofouling best practice guidelines in reducing translocation risk? *(Figure 2)*	5	4 (75)	4	13	**5**
	PP2. Test the effectiveness of "hull sterilisation" options against *Undaria* for protection of high value areas *(Figure 2)*	4	4 (75)	4	12	**4**
Contingency Plan for new introductions	CP1. Development and testing of novel eradication tools, especially for microscopic stages (including heat treatment) *(Figure 3, 4)*	5	3 (100)	2	10	**2**
Impact Management	IM1. What are the economic impacts of *Undaria* in Australia – e.g. impacts on fisheries? *(Figure 4)*	4	4 (50)	3	11	**3**
	IM2. What are the environmental impacts of *Undaria* particularly in relation to nutrient cycling, trophic dynamics and interaction with threatened species? *(Figure 4)*	3	2 (200)	4	9	**1**
	IM3. What factors influence recovery of native seaweed beds *(Figure 4)*	5	2 (150)	2	9	**1**
Monitoring	M1. Gene probe refinement & testing	2	5 (50)	4	11	**3**

Impact management

Improved understanding of the economic (Table 3; IM1) and environmental impact (Table 3; IM2) of *Undaria* 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). To adequately address this question it is very important that a clear understanding of the economic and environmental impact of *Undaria* is obtained at the local level. While the invasion process is well understood for *Undaria*[20, 21], key questions remain in relation to environmental impacts, particularly in relation to impacts on nutrient cycling and trophic dynamics. The impact of *Undaria* on the recovery of the threatened Giant kelp (*Macrocystis pyrifera*) is another key question that deserves research attention (Table 3; IM2).

While the transition from *Undaria* dominance to native seaweed dominance has been observed for small-scale (16 m^{-2}) patches[21], recovery of native algae in larger scale *Undaria* stands has not been observed. Understanding the factors that influence recovery of native algae in these circumstances should assist the decision-making process when considering options for *Undaria* control (Table 3; IM3).

Given the lack of effective control options currently available for *Undaria*, it is also important that future R&D includes on-going development and testing of innovative control options that reduce impact (Table 3; CP1). Heat treatment, as described above (see Table 3; CP1) holds particular promise in this regard and should complement programs that also include physical removal of sporophytes.

Monitoring

Gene probes are a potentially useful tool for detecting new incursions of marine pests. While a gene probe for *Undaria* has been developed, further refinement and testing is considered necessary before it can be considered an effective tool for detecting new incursions[62]. It should be noted that a review of the utility of gene probes for marine pest monitoring has recently been commissioned by the Department of the Environment, Water, Heritage and the Arts (DEWHA). As a consequence, the relative priority of gene probe development with respect to the *Undaria* 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 *Undaria* NCP. For example public awareness and education strategies aimed at reducing the spread of marine pests through management of biofouling will be applicable to *Undaria*. Additional strategies which should be considered to enhance the effectiveness of the *Undaria* NCP include:

Additional strategies – Pest prevention

Additional public awareness strategies may include targeted public awareness campaigns directed at high risk nodes where *Undaria* 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, hull fouling and aquaculture activities probably represent the greatest risk for translocation of *Undaria*. If additional public awareness strategies are developed, it is vital that stakeholders associated with these vectors 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 *Undaria* 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 what constitutes a 'significant range extension' for *Undaria* so the public can be properly educated/informed.

Due to the potentially dynamic nature of the spread and spatial extent of *Undaria*, 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 *Undaria* incursions, public awareness strategies in relation to emergency response are covered in the Australian Emergency Marine Pest Plan[33] (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 *Undaria*, the control approach (e.g. physical removal) 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 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. In a recent review significant variation in costs associated with eradication/control programs involving introduced seaweeds are clearly shown[63]. 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 a small *Undaria* population (1000 m^2) that might be considered to minimise impacts in a high value area (e.g. MPA). Manual removal by divers is proposed as an example because it is considered the only effective control option that is currently available to managers.

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. management of sea urchin predators, rehabilitation of native seaweed beds) and the capacity to implement such management depends on the jurisdiction concerned. Secondly, including habitat management within the *Undaria* budget is not considered appropriate, because these actions would result in a general improvement in ecosystem health and would be unlikely to be implemented for the sole purpose of controlling *Undaria*.

Note that salary for a project officer at a nominal level of 0.5 FTE 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 *Undaria* 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 1. Diver removal program[a] – fully funded. Staff ($30 000[b]), Boat hire ($6000[c]), Car hire ($1200[d]), Tank fills ($1440[e]), Consumables ($500[f]).	$38 060 per year	State/territory governments
	Case study example 2. Diver removal program[a] – volunteer based. Boat hire ($6000[c]), Car hire ($1200[d]), Tank fills ($1440[e]), Consumables ($500[f]).	$9140 per year	State/territory governments
	Habitat management (e.g. management of sea urchin predator populations)	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[g] per site per year	State/territory governments
	Monitoring environmental variables to evaluate impact management strategy E.g. Quarterly sampling of control and impact areas[h] Staff ($12 000[b]), Boat hire ($4000[c]), Car hire ($800[d]), Tank fills ($576[i]), Consumables ($500[f]), Data analysis and write-up ($30 000[j])	$47 876 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)	$0.7 million[k] over 3 years	Commonwealth
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 on monthly sporophyte removals, 5 diver days/month; [b] Divers cost $500/day (salary plus per diem); [c] Boat hire $500/day; [d] Car hire $100/day; [e] Tank fills based on 15 fills/month @ $8 per fill; [f] Consumables including waterproof paper, slates, stationary; [g] Cost effectiveness could be improved by surveying multiple pest species; [h] Based on 4 sites, 'impact' site and three control sites, 6 diver days/quarter; [i] Tank fills based on 18 fills/quarter @ $8 per fill; [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 *Undaria* 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 reproduction
	(iii) Increase range of effective eradication techniques	Number of effective eradication tools evaluated and available
Impact Management	(i) Prioritise *Undaria* impact management relative to other threats	*Undaria* 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 *Undaria* 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 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[59] http://crimp.marine.csiro.au/nimpis
- The Web-Based Rapid Response Toolbox[34] http://crimp.marine.csiro.au/NIMPIS/controls.htm.
- Pre-Developing Technology for Marine Pest Emergency Eradication Response[35] (in review)
- Rapid Response Manual – *Undaria pinnatifida* (under development)
- Australian Emergency Marine Pest Plan[33] (EMPPlan)
- National System Marine Pest Identification Card – *Undaria pinnatifida* (under development)

Monitoring

- Australian Marine Pest Monitoring Guidelines: Version 1 (December 2006)[56]
- Marine Pest Monitoring Manual: Version 1 (December 2006)[57]