

THREAT ABATEMENT PLAN TO REDUCE THE  
IMPACTS OF EXOTIC RODENTS ON BIODIVERSITY  
ON AUSTRALIAN OFFSHORE ISLANDS OF LESS  
THAN 100 000 HECTARES 2009

FIVE YEARLY REVIEW

## PURPOSE OF REVIEW

Under section 279 of the *Environment Protection and Biodiversity Conservation Act 1999* the Minister must review each threat abatement plan at intervals of not longer than five years. The *'Threat abatement plan to reduce the impacts of exotic rodents on biodiversity on Australian offshore islands of less than 100 000 hectares* was made by the Minister in 2009.

Reviewing threat abatement plans, at least every five years, allows for an assessment of whether the threat has been abated or, if not, what progress has been made towards abating the threat. It is acknowledged that some key actions listed in threat abatement plans may take longer than five years to achieve, such as the research required into the development of new toxins and baiting methods. The review of a threat abatement plan assesses progress and effectiveness of progress across all actions in the threat abatement plan. It also considers progress towards threat abatement in associated ways, such as related work completed through recovery plans for specific species. Finally it also considers if the threatened species are still being threatened by the subject of the threat abatement plan.

The review of a threat abatement plan provides an opinion on whether a threat abatement plan is still a feasible, effective and efficient means to abate a threat (s. 279A) and alternative options for the Threatened Species Scientific Committee to consider and advise the Minister.

## Contents

<b>Purpose of review .....</b>	<b>1</b>
<b>Executive Summary .....</b>	<b>5</b>
<b>Introduction .....</b>	<b>8</b>
<b>Objectives of the 2009 threat abatement plan .....</b>	<b>9</b>
<b>Actions.....</b>	<b>9</b>
<b>Action Group One of the 2009 TAP .....</b>	<b>10</b>
<b>Current state of actions .....</b>	<b>11</b>
Performance indicators .....	11
<b>Assessment of progress: .....</b>	<b>12</b>
1.1 – Complete state/territory databases.....	12
1.2 – Survey high-priority islands (see Background Document for options to rank islands) with no current information on exotic rodents for the presence/absence of rodents .....	12
1.3 – Formulate and circulate best-practice rules and examples to determine whether eradication is feasible .....	12
1.4 – Identify islands known to have exotic rodents where eradication is feasible, and by implication, where sustained control is the only option.....	13
1.5 – Develop a network of Australian and overseas technical experts .....	14
<b>Performance indicators.....</b>	<b>15</b>
<b>Conclusion.....</b>	<b>15</b>
<b>Action group Two of the 2009 TAP .....</b>	<b>17</b>
<b>Performance indicators.....</b>	<b>17</b>
<b>Assessment of progress: .....</b>	<b>18</b>
2.1 – Eradicate rodents from Lord Howe, Macquarie, Montague and Mutton Bird islands .....	18
2.2 – Consider Australian registration for an aerial bait with anticoagulant for use on island eradications .....	20
2.3 – Enhance skills to plan and conduct eradication operations in Australia.....	21
2.4 – Eradicate exotic rodents on other islands where high-priority conservation benefits will accrue .....	21
2.5 – Measure benefits of eradication .....	22
2.6 – Eradicate or control other pests on islands from which rodents are to be eradicated .....	23
<b>Performance indicators:.....</b>	<b>23</b>
<b>Conclusion:.....</b>	<b>24</b>
<b>Action Group Three of the 2009 TAP .....</b>	<b>26</b>
<b>Assessment of progress: .....</b>	<b>26</b>
3.1 – Review rodent control tools registered for use in Australia .....	26
3.2 – Promote trials to develop and test best-practice sequential use of rodent control tools on islands.....	34
3.3 – Train island residents or rangers as primary deliverers of sustained control on their islands	35
<b>Performance indicators.....</b>	<b>36</b>
<b>Conclusion.....</b>	<b>37</b>
<b>Action Group Four of the 2009 TAP .....</b>	<b>39</b>

<b>Current state of actions .....</b>	<b>39</b>
<b>Performance indicators.....</b>	<b>39</b>
<b>Assessment of Progress .....</b>	<b>40</b>
4.1 – Develop generic contingency plans for reaction to any new rodent invasions .....	40
4.2 – Apply quarantine systems on rodent-free islands and where eradication is achieved .....	42
4.3 – Develop island-specific contingency capabilities for islands at high risk of invasion.....	42
4.4 – Reduce risk of rodents gaining access to key vessels at key ports.....	44
4.5 – Identify and reduce the frequency of rodent infestation on key Australian vessels, i.e. those regularly berthing on priority islands .....	45
4.6 – Survey rodent species and prevalence on foreign boats that present risks to Australian islands .....	45
4.7 – Develop and test on-island prophylactic (e.g. permanent bait stations at high-risk sites) and reactive (e.g. surveillance and prompt control after any detection of rodents) strategies to detect and deal with incursions.....	46
4.8 – Develop fast response capabilities to react to shipwrecks on priority islands .....	47
4.9 – Actively involve island residents and ship owners in the management of incursion risks .....	47
<b>Performance Indicators.....</b>	<b>48</b>
<b>Conclusion.....</b>	<b>50</b>
<b>Action Group Five of the 2009 TAP .....</b>	<b>52</b>
<b>Current state of actions .....</b>	<b>52</b>
<b>Performance indicators.....</b>	<b>52</b>
<b>Assessment of Progress .....</b>	<b>52</b>
5.1 – Promote stakeholder input and involvement as the Threat Abatement Plan is implemented .....	52
5.2 – Actively consult with traditional owners of islands.....	54
5.3 – Promote the conservation benefits of successful eradications to the wider Australian public .....	54
5.4 – Identify boat owners who visit key islands, and develop an education package to ensure their vessels are free of rodents.....	56
<b>Performance Indicators.....</b>	<b>56</b>
<b>Conclusion.....</b>	<b>57</b>
<b>Action Group Six of the 2009 TAP .....</b>	<b>59</b>
<b>Current state of actions .....</b>	<b>59</b>
<b>Performance indicators.....</b>	<b>59</b>
<b>Assessment of Progress .....</b>	<b>60</b>
6.1 – Determine why mice appear to be more difficult to eradicate in the presence of rats .....	60
6.2 – Develop best-practice guidelines for sustained control of rodents on islands.....	60
6.3 – Improve the humaneness of eradication tools .....	61
6.4 – Develop and test risk-based methods to detect and manage incursions by rodents.....	63
6.5 – Predict and test the consequences of prey switching .....	63
<b>Performance Indicators.....</b>	<b>64</b>
<b>Conclusion.....</b>	<b>64</b>
<b>Conclusion on the 2009 threat abatement plan .....</b>	<b>67</b>
<b>Looking forward .....</b>	<b>67</b>
<b>Appendices.....</b>	<b>68</b>

<b>Appendix A: <i>Threatened species listed under the EPBC Act or in state/territory legislation (as noted in the tables) that are affected or potentially affected by exotic rodents on islands under 100 000 ha</i></b> .....	<b>68</b>
<b>Appendix B: Macquarie Island additional information</b> .....	<b>70</b>
<b>References:</b> .....	<b>73</b>

## EXECUTIVE SUMMARY

The goal of the 2009 Threat Abatement Plan to reduce the impacts of exotic rodents on biodiversity on Australian offshore islands of less than 100 000 hectares was to eliminate, or reduce to an acceptable level, the current and future impacts of exotic rodents on offshore Australian islands to ensure the survival of native species and ecological communities. While success in key projects such as Macquarie Island has led to some significant advances in the way that rodent eradication and management is approached, there is still more progress that can be made on how this work is prioritised, assessed and promoted as a viable conservation strategy.

Action group one aimed to establish an information base upon which the prioritisation and sequencing of conservation actions such as eradications, quarantine and biosecurity plans could be determined. Some progress has been made on these actions through the publication of two reports as well as the establishment of the Feral Animals on Offshore Islands Database in 2008. These publications represent a resource that, together, could potentially provide data to enable the prioritisation of eradication projects and other conservation actions by land managers. They will also allow for adaptive management through examination of previous eradication and management projects. Another achievement is the establishment of Island Arks Australia and participation by various experts in activities and symposia hosted by this network on island conservation. This network and the symposiums have provided an invaluable sharing of knowledge, current research, and practical experience in the restoration of island ecosystems.

The purpose of action group two in the 2009 TAP was to encourage state and territory governments to progress various eradication projects on priority islands (including Lord Howe, Macquarie, Montague and Mutton Bird Islands). It also aimed to build capacity across these agencies to plan and implement eradication projects, improve the tools for eradication and measure the benefits these projects and their outcomes deliver. To date, eradications have been conducted on Macquarie, Montague and Muttonbird Islands. An increase in the capacity and skills of state and territory agencies to conduct eradication projects has been further developed by members of agencies involved in the key eradication projects such as those mentioned above. While some progress has been made on the sharing of information through journal articles and through meetings such as the Island Arks Symposiums, these forums are not frequent enough to elicit a consistent sharing of knowledge and expertise across multiple agencies.

Action group three had the aim of achieving sustained control on priority islands where eradication of rodents was not a feasible option and examining control tools available for both control and eradication projects. A review of toxins for vertebrate pests has been produced by the NSW Department of Primary industries (McLeod and Saunders, 2013) and while this document is not specific to rodents, it contains information on all the chemical control agents currently registered for vertebrate pest control. A good body of accumulated experience in applying these tools has been developed during the eradication projects over the past five years. On the ability to maintain sustained control of rodents on islands, the training of island residents as rangers and land managers has progressed through the Working on Country and Caring for Our Country programs. The establishment and continued support for Indigenous ranger programs by the Australian government has been beneficial to island communities and has increased the capacity of island residents to manage their island's environment and achieve sustained control of rodent pests, where required.

Action group four was to pursue measures to reduce the risk of the invasion or reinvasion of priority islands with actions in two areas. The first was to put in place quarantine plans on these islands including contingency plans for new rodent incursions. The second was to determine the prevalence of rodents on vessels visiting these islands, and limit their access to these vessels and control them where necessary. Quarantine or biosecurity plans that have proven to be effective in preventing reinvasion are in place on Barrow Island and Macquarie Island already, with an improved biosecurity plan in draft for Macquarie Island amongst others.

The objective of action group five was to ensure that the threat abatement plan's actions and outcomes were understood and actively supported by island residents and to achieve public outreach and education on the benefits of island conservation actions.

For public outreach on island eradication and conservation projects, both the Montague Island eradication project and the Macquarie Island eradication project have had success in promoting their actions and the benefits of these to the public. However, a number of other successful eradication and control projects across Australia (such as those carried out in WA on Boullanger and Whitlock islands amongst others) have received minimal attention. The promotion of the TAP to interested stakeholders is seen in projects funded through the Caring for Our Country program. This has led to some exposure of the TAP and its goals and objectives to stakeholder groups involved in these projects. Apart from this however, there is little evidence to suggest that the broader promotion of the TAP has been successfully accomplished in the past five years.

The objectives of action group six were designed to meet the information needs for future projects through research. Experience in both eradication and sustained control, and the techniques and strategies around these activities, has been developed in Australia and New Zealand through projects such as Barrow Island, Montague Island and Macquarie Island. Research based upon the results of some of these projects has led to greater knowledge of island eradications including: mouse/ rat interactions; best practice methods for both the control and eradication of rodents on islands; and improvement to the humaneness of control tools and methods to monitor for new rodent incursions. Despite these additions to our knowledge the collation of this knowledge has been inconsistent. A more standardised and concerted approach to examining and disseminating new knowledge in island conservation is required to ensure that new projects are able to use the best practice techniques from the outset.

The review of this TAP has determined that there have been some significant advances in: the techniques, tools and tactics employed in the eradication of rodents. There have also been advances in how other conservation actions on islands are approached in quarantine and surveillance of rodent free islands and the involvement of island residents and traditional owners in the conservation process. Despite this, the monitoring of eradication actions and the sharing of the knowledge gained through completed projects has not been entirely successful, and a number of priority islands are still affected by invasive rodents. A reprioritisation of islands requiring conservation action may be needed and a more concerted emphasis on monitoring and reporting of all eradication projects needs to be strongly considered. Therefore, it is the conclusion of this review that a revision of the threat abatement plan to reflect these changes is needed to reduce the impact of invasive rodents on the biodiversity of Australia's offshore islands.





## INTRODUCTION

Exotic mammals, particularly rodents, have been a major cause of extinction and decline of island biodiversity around the world; with species on islands comprising the majority of all extinctions over the last millennium. Australian islands have been no exception, especially since European colonisation, with exotic rodents (as well as feral cats, foxes, rabbits, feral goats, feral pigs, reptiles, amphibians, exotic invertebrates, and weeds) being responsible for the extinction (loss of the entire species), extirpation (loss from one island), or decline of many native species, and for many adverse changes to insular ecosystems.

In 2006, the Australian Government listed exotic rodents on islands as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and initiated the development of the 2009 threat abatement plan for rats and mice on islands less than 100 000 ha in area. This document aims to review the current progress of the actions and objectives proposed in the 2009 plan and to provide advice on whether a plan is still required to abate the threat.

## **OBJECTIVES OF THE 2009 THREAT ABATEMENT PLAN**

The plan contains three objectives, and a series of actions that will be required to achieve them. Knowledge gaps and other constraints and uncertainties and the need for stakeholder commitment and capacity building are identified in each strategic objective. The objectives to reduce the impacts of exotic rodents on biodiversity on Australian offshore islands of less than 100 000 hectares are to:

- eradicate exotic rodents from high-priority islands
- mitigate the impacts of exotic rodents on biodiversity values on high-priority islands where they cannot be eradicated, and
- prevent the invasion of islands currently free of exotic rodents.

### **Actions of the 2009 TAP**

The following actions were proposed under the plan. They were in part sequential although different jurisdictions were involved at different points during the process, therefore the judgement about their relative priority may have varied between jurisdictions.

The first set of actions aimed to provide better information on the conservation status of islands as these are affected by exotic rodents. The next two sets of actions prescribed alternative strategies (eradication or sustained control) that were to be used to manage islands with exotic rodents. The fourth set of actions prescribed how to stop the problem getting worse and how to defend islands from which exotic rodents have been eradicated. The next set of actions introduced the social and cultural needs of islanders and other stakeholders to ensure they supported actions to control rodents, benefit from these actions, and participate in ongoing management such as quarantine and surveillance. The final actions identified the priority needs for research and information on rodents and their interactions with island ecosystems.

Priorities were ranked as very high, high or medium within each set of actions and this indicated when each should be started. The timeframes supplied with these actions gave an initial indication on how long each action might take to achieve. Generally, a short timeframe indicated a 1 – 3 year action, a medium timeframe up to 5 years, a long timeframe indicated an ongoing effort but with a definite end point, and an ongoing timeframe has no endpoint but would require investment in perpetuity. Decisions around the priority score and timeframe were intended to be interactive, the sets of actions were meant to be interdependent, and the final sequence, duration and length of actions were to be dependent on budgets.

## **ACTION GROUP ONE OF THE 2009 TAP**

### **3.3.1 Actions to set priorities and plan strategic options**

The 2009 TAP stated:

This group of actions covers the preliminary information needs and actions required to establish a basis for implementing the plan. The key questions the actions aim to answer are:

- Which islands, whose rodent status is unknown, might be of concern if they were present? These islands should be surveyed and brought into the following selection process should they be discovered to have exotic rodents.
- Which islands known to have exotic rodents are candidates for the preferred option of eradication and which, by implication, would require sustained control?
- Which islands that are candidates for eradication should be treated first, and where should sustained control be started?

Two parallel processes need to be followed to answer these questions. The first process (actions 1.1 and 1.2) is a prioritisation system to select islands for survey where information is lacking, or to confirm information on islands where the status (presence or species) of exotic rodents is unclear. The second process aims to identify whether eradication is feasible on each island and then prioritise those islands for action (actions 1.3 to 1.5). Past success on similar islands and species, or analyses of the island-specific rules and constraints, can be used to judge this. For these islands, a second prioritisation process is required. Generally, precedence should be given to those where there is a clear current threat to native species or communities and where substantial benefits to the island's biodiversity would be expected if the rodents were eradicated. This rule tends to favour remote islands because of the vulnerability of their biota and their higher levels of endemism. However, cases can be made for eradication on inshore islands by some jurisdictions either to act as arks for mainland biota or as demonstration or capacity-building sites.

1 - Actions to set priorities and plan strategic options	Priority and timeframe
1.1 Complete state/territory databases	High priority, completed in 2008
1.2 Survey high-priority islands (see Background Document for options to rank islands) with no current information on exotic rodents for the presence/absence of rodents	Medium priority, timeframe depends on State needs
1.3 Formulate and circulate best-practice rules and examples to determine whether eradication is feasible	High priority, short term
1.4 Identify islands known to have exotic rodents where eradication is feasible, and by implication, where sustained control is the only option	Very high priority, short term
1.5 Develop a network of Australian and overseas technical experts	Medium priority, medium term

## **Current state of actions**

The Department of the Environment contracted the collation of data on the presence of vertebrate species (including exotic rodents) on Australian islands. However, significant uncertainties remain in the databases. Rodents may be present on some islands despite not being found during surveys, or found but not noted in the literature. Rodents are also known to be present on some islands but the exact species remains unclear. Many islands, some with high biodiversity values, have not been surveyed for exotic rodents.

The setting of national or regional priorities would be improved with more complete information on the presence/absence of particular exotic rodent species; and feasibility or operational planning for any island would require information on both the exotic rodents and non-target species.

Action 1.4 might be completed at a national level using current data (e.g. see Table 2.3 in the *Background document to the Threat abatement plan to reduce the impacts of exotic rodents on biodiversity on Australian offshore islands of less than 100 000 hectares* (DEWHA 2009). The outcomes of this would provide state and territory agencies with a clear guide to prioritise and set timetables for eradication or sustained control among the islands in their jurisdictions (see actions under 3.3.2 and 3.3.3 below).

## **Performance indicators**

- The current island databases are updated periodically, and any islands with high-priority conservation values such as threatened species or unique communities, but with uncertain rodent status, are checked.
- Templates of best practice feasibility studies and operational plans on rodent eradication are circulated to key state and territory agencies and used to develop capacity and the network of experts.
- A national list of the highest priority islands for eradication is developed.

## **Assessment of progress:**

### **1.1 – Complete state/territory databases**

The *Feral Animals on Offshore Islands Database* was completed in July 2010 and has since been maintained by the Department of the Environment's Environmental Resources Information Network (ERIN). This database contains information supplied by state and territory governments as well as the departments own resources to compile a list of offshore islands greater than 20 hectares where invasive and feral species have been recorded as being present. The database contains 2,000 records for 154 species on 523 islands.

Whilst this database has provided a useful resource for many involved in island conservation, it has been infrequently and haphazardly updated. This has caused the database to become dated in certain aspects of its information. However, it continues to remain an important resource.

### **1.2 – Survey high-priority islands (see Background Document for options to rank islands) with no current information on exotic rodents for the presence/absence of rodents**

On a national scale there has been very little collation of rat and mice surveys on islands since the Ecosure report was conducted in 2009 (Ecosure, 2009). Some individual islands have likely been surveyed by the relevant state agencies prior to an eradication project commencing, but these efforts have been piecemeal with no organised survey of a number of islands.

Some of the states have recorded attempted eradication projects within their jurisdictions and this has been further compiled by the Invasive Animals Cooperative Research Centre (Gregory et al 2014) into the AusErad database. This database identifies all known attempts to eradicate a species from an island. However, Gregory et al (2014) addressed only past eradication attempts and their success and did not venture into prioritising islands for future action. An opportunity therefore exists to build upon the work already completed by updating the list of priority islands for conservation action based upon the islands that have been subject to conservation actions and by incorporating the lessons learned from these projects into the prioritisation process. This work would need to be undertaken collaboratively with all state and territory governments as well as relevant experts in this field (both academics and land managers) and could be a highly useful tool for future work.

### **1.3 – Formulate and circulate best-practice rules and examples to determine whether eradication is feasible**

In regards to the development of national best practice examples, little has been done at the national level despite this action being a high priority action in the TAP.

The Pacific Islands Initiative management guidelines, '*Guidelines for invasive species management in the Pacific: a Pacific strategy for managing pests, weeds and other invasive species*' (SPREP, 2009) provides a good example of a comprehensive and practical best

practice guideline document. This document covers the process of setting up, organising, and managing eradication or management programs for invasive species at a regional level. If a set of national best practice guidelines were to be drafted this could act as a good template for its development.

The paper “*Eradications of vertebrate pests in Australia: A review and guidelines for future best practice*” (Invasive Animals CRC 2014) reviews the current available literature on eradication practices and examines those eradication projects attempted in Australia on both offshore islands and on the mainland (Gregory et al 2014). However, this document focuses more on the overall trends and indicative factors in eradication success in Australia than it does on the accumulated practical experience of how to undertake eradication projects. As such, it is a useful record and comparison of eradication projects but is less useful as a practical guide to best practice eradication techniques.

Another source of information is a number of island eradication projects in WA undertaken using funding provided by the Caring for Our Country program. These projects, which involved the participation of Western Australian Department of Environment and Conservation officers, between 2009 and 2012 and aimed to eradicate rodents from Boullanger, Whitlock, Three Bays, Faure, Thevenard, Figure of Eight, Sunday, Long, Boxer, Woody, Mistaken and the Direction (Cocos Keeling) Islands (Caring for Our Country, 2009). The experience gained from these eradication attempts across a number of different islands under varied conditions could contribute significantly to the development of best practice guidelines for rodent eradication projects on islands.

#### ***1.4 – Identify islands known to have exotic rodents where eradication is feasible, and by implication, where sustained control is the only option***

The report by Ecosure (2009) for the Department of the Environment, which prioritises offshore islands on the basis of conservation values, is the most comprehensive ecological review of Australia’s offshore islands to date. This report identified 100 islands of priority for conservation action, including Lord Howe, Montague, Mer, and Muttonbird Islands. However, state and territory agencies often apply their own criteria to the application of limited conservation resources.

Macquarie Island is a good example of a program that is completed that demonstrates sustained and effective control practices. Sustained rodent eradication efforts on this high priority island have been remarkably successful with the complete eradication of both rats and mice being announced in early 2014 (the inception and process of this program are discussed in detail in Action group 2). The ongoing monitoring and quarantine efforts in place to prevent the reinvasion or resurgence of rodents on the island have thus far proven effective and will be further strengthened in future by the implementation of a biosecurity plan being developed by the Australian Antarctic Division and Tasmania Parks and Wildlife Service.

Another successful eradication project was undertaken on Mer Island in the Torres Strait Islands. This project took place between December 2009 to 31 December 2012, under the supervision of the University of Queensland’s Dr. Luke Leung and with funding from the Caring for our Country program. The purpose of the project was to attempt the eradication of ship rats and house mice from the entirety of Mer Island. The project used bait stations strategically placed around settled or disturbed areas of the island (these areas were determined to have the highest density of non-native species, with the native grassland *Murumys* (*Melomys*

*burtoni*) extirpating the invasive species from the less disturbed natural habitat). In total, the island was subjected to nine rounds of baiting over the four year project, with the eradication declared a preliminary success at the end of this period.

Lord Howe Island is another example of an island that has been identified as requiring an eradication program for rodents, but for which a program has not yet been fully implemented. The island authorities and NSW Parks and Wildlife have undertaken ongoing control of rodents around the main settlement and within the kentia palm plantations on the island, but no island-wide control has been attempted to date (Lord Howe Island Board 2009). A rodent eradication plan for the entire island had been drafted and approved by NSW Parks and Wildlife Service (Lord Howe Island Board, 2009) and would involve the island-wide application of brodifacoum. However, due to concerns about the proposed plan from the island community, the implementation of this plan has been delayed (NSWPWS 2014).

Some state governments have identified islands which they consider to be a priority and on which they believe eradication and control programs are a feasible option for the conservation of these islands (e.g. Priddel et al., 2011). However, none of the prioritisation of these efforts have been subject to direction at the national level. The lessons in eradication, monitoring and quarantine from successful projects such as Macquarie Island and Mer Island, amongst others, should be learnt from and re-employed for the remaining priority islands (either those identified in the 2009 Ecosure report or other islands identified by state and territory agencies as being of high priority for conservation action).

### ***1.5 – Develop a network of Australian and overseas technical experts***

The actions which most closely match the development of a network of Australian and overseas technical experts is the formation of the group Island Arks Australia. This group began its work by holding the first Island Arks Symposium in the Whitsunday Islands in December 2009. This first symposium established a group of Australian and international experts with a specific interest in, and knowledge of, the conservation of species and ecosystems on islands. This is a loose network, which predominantly keeps in regular contact through symposiums and the Island Arks website (<http://islandarks.com.au>) and endeavours to keep up to date with the latest research in island conservation, control techniques for invasive species, and other affiliated subjects.

In addition to this organisation, Island Net was a newsletter established in partnership between the Department of the Environment and the Invasive Animals CRC in 2009. This newsletter was designed to draw together a network of island managers and conservationists, especially related to invasive species, to share information on successful conservation projects on islands or the progress of these efforts. The Island Net newsletter was published from 2009 – 2012.

The continuation of Island Arks Australia will contribute to addressing this action. However commonwealth, state and territory government support for this group should be encouraged, where possible.

## Performance indicators

1. *Templates of best practice feasibility studies and operational plans on rodent eradication are circulated to key state and territory agencies and used to develop capacity and the network of experts.*

Since the making of the 2009 TAP there has been little to no action taken to produce or distribute either examples of, or standards for, the best practice management of rodents on islands (apart from the guidelines document produced by the Invasive Animals CRC) (Gregory et al 2014). There are however, a number of examples of working management plans on specific islands in Australia and internationally, as well as operational guidelines currently being used in other countries that may represent best practice standards. A good example of the kind of guidelines that can be developed is the *Guidelines for the management of invasive species in the Pacific* produced by the Pacific Islands Initiative (SPREP, 2009). This document outlines the processes, logistics and planning required to implement a broad scale control program for invasive species. As raised earlier in this review, the experience and expertise exist in Australia to produce such templates and circulate them to states as a resource. This action would be better achieved by incorporating the production of these templates as a part of the development of the Best Practice guidelines under in Action 1.3, rather than as a separate project.

2. *A national list of the highest priority islands for eradication is developed.*

A list of priority islands were developed through the Ecosure report in 2009, but this list is now dated, inaccurate in some areas, and does not have a sole focus on rodents. Individual state governments have priorities of their own concerning islands for eradication action, which again do not focus solely on rats and mice (e.g. NSW eradication program on their islands (Priddel et al., 2011)). The priorities set by the state governments may have a basis in the protection of a high biodiversity island, or may simply be reflective of what that particular authority had resources to do at the time. Very little additional work has been undertaken to update or improve upon the original priority list included in the Ecosure report. The *Feral Animals on Offshore Islands Database*, as maintained by the Australian Government Department of the Environment, has had limited input to update its contents from the states.

A list of priority islands such as the one in the Ecosure report could be updated to produce a national level list. The revised list could be based upon information on state activities over the last 5 years and information from relevant literature including the Invasive Animals CRC report (Gregory et al., 2014). This activity is likely to be useful for directing funding to these priority projects from sources such as the National Landcare Programme. Further funding to support rodent eradication on islands will be required from state and territory governments and NGOs.

## Conclusion

This action group aimed to establish an information base upon which the prioritisation and sequencing of conservation actions such as eradication, quarantine and biosecurity plans can be determined. It also aimed to provide a number of examples and guidelines to direct planning for the implementation of these projects.



A small amount of progress has been made in addressing the actions within this group through the publication of two reports (Ecosure 2009, Gregory et al., 2014), as well as the establishment of the *Feral Animals on Offshore Islands Database* in 2008. These publications represent a resource that, together, could assist land managers with prioritising islands and the eradication projects and other conservation actions required (Offshore islands database)(Ecosure, 2009). They would also allow land managers to apply adaptive management practices by examining previous eradication and management projects and some of the factors that may have contributed to their success (or failure) (Gregory et al., 2014).

As the offshore islands report by Ecosure and the offshore islands database both represent ageing resources, these will require updating in the near future to retain their usefulness to land managers and conservationists.

The review document released by the Gregory et al in early 2014 represents a comprehensive and up to date examination of the attempted eradications in Australia in recent history and examines the data with a view to providing:

- Island characteristics that may indicate how likely an eradication attempt is to succeed
- Examples of 'best practice' to guide future activities in this field, and
- Gaps in our current knowledge of eradication techniques and invasive species management and future research priorities.

While this paper is useful in examining our current knowledge, providing examples of previous eradication projects and identifying future directions for research, it provides minimal practical guidance to a land manager or conservationist wishing to undertake similar projects.

Another achievement has been the establishment of the organisation Island Arks Australia and it's network of subject matter experts and land managers and the participation of other relevant stakeholders in activities and symposia hosted by this network on island conservation. This network and the symposiums have provided an invaluable sharing of knowledge, current research and practical experience in conducting conservation through eradication and management of invasive species and the restoration of island ecosystems.

In conclusion, there have been some advances in creating a priority list of islands and identifying islands both eligible for eradication and those that require protection. There have also been some minor advances in establishing a body of knowledge on the implementation of eradication projects and the interlinking of a community of experts in this area. However, apart from these accomplishments, there has been a lack of activity at the national level to produce guidelines and best practice management examples to guide states and others in the delivery of eradication projects. Further, while a national priority list of islands has been created, it requires updating to remain a useful resource. As such, the development of best practice guidelines and the maintenance of a comprehensive and current priority list of offshore islands still remains a relevant action.

## **ACTION GROUP TWO OF THE 2009 TAP**

### **3.3.2 – Actions to achieve eradication as set out in the 2009 TAP**

The 2009 TAP stated:

This group of actions suggests state and territory governments and other land managers use the national list produced in action 1.4 to progress eradication of exotic rodents on islands in each jurisdiction.

The action to start the planning process for additional islands has not yet been progressed, as land managers are awaiting the outcomes of eradication programmes on the two large islands (Macquarie and Lord Howe). If rodents are eradicated from these two islands then other remote, large islands with significant biodiversity values at risk (e.g. Norfolk, Christmas, Cocos Keeling) might be considered. If the rodents are not eradicated from Macquarie or Lord Howe, then further research to identify the failure points and potential solutions would be required before attempting eradication on other large islands. The initial priorities might switch to achieving success on smaller islands, perhaps with a single species of exotic rodents as the priority. Whenever possible in undertaking research on, or control of, exotic rodents on islands, the disease status of the species (and, where appropriate, co-occurring native mammals) should be assessed. Such assessment will help refine the evaluation of risks and the prioritisation of control for island occurrences of exotic rodents.

The final actions in this section are to ensure the benefits of successful eradication of exotic rodents are measured, known to stakeholders and celebrated, successes are defended against re-invasion by rodents (expanded in section 3.4.4), and removal of exotic rodents is seen as an opportunity to manage other threats present on the island. The benefits of removing rodents will be island-specific. These might extend from the re-categorisation of a listed threatened species to a safer category, to the contingent opportunities to return extirpated species to the island.

<b>2 - Actions to achieve eradication</b>	<b>Priority and timeframe</b>
2.1 Eradicate rodents from Lord Howe, Macquarie, Montague and Mutton Bird islands	Very high priority, short to medium term
2.2 Consider Australian registration for an aerial bait with anticoagulant for use on island eradications	Medium priority, medium term
2.3. Enhance skills to plan and conduct eradication operations in Australia	High priority, ongoing
2.4 Eradicate exotic rodents on other islands where high-priority conservation benefits will accrue	High priority, long term
2.5 Measure benefits of eradication	High priority, ongoing as projects are conducted
2.6 Eradicate or control other pests on islands from which rodents are to be eradicated	High priority, ongoing as projects are conducted

#### **Performance indicators**

- Exotic rodents are eradicated from Macquarie, Lord Howe, Mutton Bird and Montague islands, or causes of failure identified.
- A bait with an anticoagulant toxin is registered for use for the eradication of exotic rodents on islands.

- The first tranche of islands identified as high priority for eradication are introduced into state and territory planning processes.
- All eradication plans identify and monitor pre- and post-eradication indicator native species expected to benefit from eradication of exotic rodents, and indicator native species that may be at risk from the control methods.
- All eradication plans consider the costs, benefits and risks of including other invasive species present on the island within the planning process.

### **Assessment of progress:**

#### **2.1 – Eradicate rodents from Lord Howe, Macquarie, Montague and Mutton Bird islands**

##### **Lord Howe Island:**

Many attempts have been made to control invasive ship rats (*Rattus rattus*) and house mice (*Mus muscalus*) on Lord Howe Island since their first arrival in 1920. The current control program involving the limited use of brodifacoum baits, is small scale (\$65,000 per annum cost to control rodents on only 10% of the island's land mass) and largely focuses on the commercial ketia palm forest (which has remained largely unchanged since 1986). In the 2009 draft eradication plan for the island, it is acknowledged that the current program is insufficient to deliver the long term control of invasive rodents on the island or to achieve any long term conservation benefits (Lord Howe Island Board, 2009).

The proposed eradication programme will distribute brodifacoum based poison baits (Pestoff 20R®) by aerial and hand broadcasting to all parts of the island group, except Balls Pyramid (as it is thought to be free of rodents). Two baiting periods will be undertaken 14 days apart to ensure the island group is covered with sufficient bait so that all rodents present are exposed to the baits and as many mice and rats are eradicated as possible. Although the islets surrounding Lord Howe island are believed to be clear of rats and mice, these islets will be baited to reduce the risk of reinvasion and the failure of the eradication programme (Lord Howe Island Board, 2009). The proposed island wide eradication plan has had its implementation delayed by a number of factors since the original proposed starting date of 2010. This is partially due to community concerns which have been raised in relation to some aspects of the project — discussions with the community are continuing. At present, the full implementation of the baiting program and the ancillary actions are proposed to begin in 2016.

##### **Macquarie Island:**

The eradication program for rodents on Macquarie Island was first commenced in 2005 and aimed to remove all remaining vertebrate pests from the island (rabbits, ship rats and house mice) and restore the island to the conditions that existed prior to the introduction of these species. In order to achieve this aim, the eradication program faced many challenges. Some of these included the remoteness of the island (with its location in the sub-Antarctic) and the logistical challenge of transporting the necessary equipment and personnel in order to undertake the various phases of the eradication programme. In order to successfully achieve the transport phase of the eradication, the project managers needed to take into account both

the remoteness of the island and the often inhospitable weather conditions experienced during winter (the optimum time for baiting) (Tasmanian Parks and Wildlife Service, 2010a).

The timing of the baiting programme for the winter period between May and August was determined to be of high importance for the following reasons:

- There would be less available food resources on the island for the selected invasive species, meaning higher potential uptake of baits and increased impact of the bait drops
- There would be lower population levels of the targeted pest species due to non-breeding season and lower resource availability
- There would be lower resident population levels of potentially susceptible non-target species (native animals) due to the non-breeding season which would reduce secondary impacts from the baiting drops, and
- It is during the low season for tourist traffic to the island, ensuring a minimum of people on the island at the time of baiting.

The bait drop operation was initially intended to be completed in the winter of 2010 (May to August), but was delayed, and eventually cancelled, by adverse weather conditions. Despite the cancellation, a small portion of the island (about 8%) was successfully baited during this period. The baiting was very successful in killing the target species within the 8% covered; however there was some anticipated incidental mortality of non-target seabirds after the application of bait in June 2010 (Tasmanian Parks and Wildlife Service, 2014). The second baiting season between May and July of 2011 comprised two whole-of-island bait drops and a third bait drop to target high risk areas such as rock stacks and the penguin colonies on the south of the island. This delayed program began on the 3rd May 2011 and was finished on schedule within seven weeks. In order to further mitigate the risk of secondary poisoning to scavenging seabirds the project staff conducted follow-up manual collection and disposal of poisoned carcasses during the baiting period (Tasmanian Parks and Wildlife Service, 2014).

On the completion of the bait drops and cleanup operations in 2011, the monitoring phase of the project was immediately initiated in July 2011. This phase involved trained field teams being deployed to locate and kill any remaining rabbits, rats or mice that may have survived the baiting programme. This involved shooting and spotlighting, fumigating burrows, the use of specially trained hunting dogs, and a trapping schedule to search for remnant rodents. The monitoring programme was concluded in the second half of 2013 with no signs of any of the three target rodent species detected; in fact no rats have been detected on the island since May 2011, and no mice or rabbits had been detected since June 2011. As a result, in April 2014, Macquarie Island was declared pest free, bringing this highly successful eradication programme to a close (Department of the Environment, 2014a).

A biosecurity and island customs plan is also being produced by Tasmanian Parks and Wildlife Service and the Australian Antarctic Division (AAD) and will be put into force when drafting and the details of its implementation is agreed to between the relevant parties.

### **Montague Island:**

The rodent control program on Montague island was conducted in 2007 as a part of a broader project instituted by the NSW Office of Environment and Heritage to eradicate pest species from a number of key islands off the NSW coastline (Priddel et al., 2011).

This eradication project aimed to concurrently remove both European rabbits (*Oryctolagus cuniculus*) and house mice (*Mus muscalus*) from the island, by taking advantage of a reduction in rabbit numbers caused in part by an outbreak of *Calici* virus in 2005. The operation involved two aerial applications of bait containing brodifacoum. Sowing rates were 12 kg per ha for the first drop and 6 kg per ha for the second, with ten days between applications. One month after the baiting program was completed, 75 tracking tunnels were distributed alongside tracks on the island. These were monitored for mouse activity (footprints) every three months over a two year period. In addition, up to 100 Elliott traps and seven remotely activated cameras were deployed in response to any reported sightings of mice (Priddel et al., 2011)

By the end of 2007, it is believed that all pest rodent species had been eradicated from Montague Island through a combination of a baiting program (using Brodifacoum based cereal baits), a monitoring and biosecurity program, and in the case of the island's rabbit population, the introduction of Rabbit Hemorrhagic Disease (RHD) onto the island in 2005. (Priddel et al 2011). Since the removal of the rodents, several species of burrow nesting bird have returned to the island (NSW Parks and Wildlife media).

### **Muttonbird Island:**

This 'island' has been subject to eradication efforts, although, as it is joined to the mainland by an artificial isthmus, some consider it not to be a true island. Since 2009 the 'island' has been subject to an eradication and management plan to protect the breeding colony of wedge-tailed shearwater (*Ardenna pacifica*) (National Parks and Wildlife Service NSW, 2009). This program has had some limited success in protecting shearwaters from reinvasions of rats, foxes and cats from the mainland. However, it has shown an increase in the breeding success of shearwaters since the program has been in place.

## **2.2 – Consider Australian registration for an aerial bait with anticoagulant for use on island eradications**

Brodifacoum is registered in all states and territories for the control of introduced rats (*Rattus* sp.) and mice (*Mus musculus*), especially warfarin-resistant strains. The use of this active ingredient in baits for vertebrate pest control is restricted to being used in and around buildings, not in open areas (McLeod and Saunders, 2013). Despite this restriction, brodifacoum based baits are used extensively for eradications of pest vertebrate species such as the recently completed eradication of rats and mice on Macquarie island. The use of these baits in this "off label" manner is regulated by the APVMA via a system of minor use permits which must be individually obtained for each project. No application for the broader off label use of brodifacoum based baits has been submitted to the APVMA (APVMA, 2014). However, the company that supplied the bait for the Macquarie Island eradication project (Animal Control Products, New Zealand), have indicated that they intend to pursue the registration of the

brodifacoum active for broad scale use and for an analogous product to the Pestoff 20R<sup>®</sup> rodent bait used in the Macquarie Island eradication project (Bill Simmons pers. comm. 2014).

### **2.3 – Enhance skills to plan and conduct eradication operations in Australia**

Since the 2009 Threat Abatement plan was drafted, many eradication projects have been either commenced or largely completed by various state agencies on their priority islands. One of the primary examples of this is the eradication program for rodents instituted (and now in its final stages) on Macquarie island (see detailed information in Action 2.1 above). The knowledge and experiences gained over the last four years of this project provide an excellent base for the planning and execution of other conservation projects in Australia. The outcomes may also form a base for a national best practice document for island eradications (as recommended under other TAP actions).

Other projects (either currently underway or completed) that have developed experience, knowledge and skills in invasive species eradication and may be able to contribute to guidelines on how to conduct these operations in Australia include the following:

**Barrow Island- WA:** The Barrow Island quarantine project, funded and administered by Chevron Energy Corporation, represents an example of best practice in quarantine procedures and technology for biosecurity on islands. Although this level of protection is not always achievable, this project represents a highly effective quarantine and monitoring model for offshore islands and could be used as a primary example for post-eradication best practice.

**Mer Island- Torres Strait:** The *Mer Island Biodiversity Management Profile* was published in 2013 and includes a breakdown of the biodiversity assets of the island and sets out plans for their conservation. Although this plan is only newly established, its concepts could be useful in determining priority for eradication actions based upon the key biodiversity assets present. In addition to this, there have been some past efforts to eradicate mice and rats from Mer Island. This knowledge and experience, including effects upon biodiversity, could be useful for other projects.

**Montague Island- NSW:** Montague Island was declared free of mice and rabbits in 2009. The program was conducted on a small budget and entirely by NSW Parks and Wildlife staff with the assistance of the NSW Office of Environment and Heritage. This experience will assist in the training of other staff to conduct similar eradication programs in the future, both within NSW and elsewhere.

**The Tiwi Islands group ranger program/ Working on Country:** In 2006, the Tiwi Islands ranger program was started to fill a gap in capacity for land management in this remote area. In the course of their duties, the Indigenous rangers have taken part in several eradication efforts. They are able to provide a great deal of on-ground operational and program experience, particularly where there are limited resources.

### **2.4 – Eradicate exotic rodents on other islands where high-priority conservation benefits will accrue**

As mentioned above, there have been several projects which are either planned, underway or completed since the making of this TAP in 2009. Most of these projects have been conducted at their respective locations due to the high biodiversity and conservation outcomes that are

likely to arise from the eradication of invasive rodents and the subsequent restoration of habitat resulting from these actions.

While the measurable conservation benefits from these eradication projects are yet to be fully quantified, there are studies underway to determine the rate of recovery of native species post eradication. On Macquarie and Montague islands, there has been a noticeable rebound in both populations and breeding activity for many bird species which were either severely affected by, or in some cases completely extirpated from these islands by, pressure from invasive species such as rats and mice. There is a great deal of evidence in the literature to demonstrate the benefits to conservation from the removal of invasive species from islands.

There have been a number of eradication projects (in addition to those islands identified in Action 2.1) carried out on islands over the past five years (e.g. Broughton islands, Brush and Looking Glass Island in NSW (Priddel et al., 2011)). However, the measurement of the conservation benefits to native species for these projects is quite often limited to one-off surveys or incidental observations during the course of other work. In addition, the lack of dedicated monitoring before, during, and after an eradication program, has meant that the benefits to biodiversity outcomes are often difficult to conclusively prove.

The selection process used by the various states to determine which islands receive conservation effort via an eradication attempt does not seem to follow the priority list supplied in the offshore islands report by Ecosure (Ecosure, 2009). This may be due to each state and territory having its own priorities, or it may be due to an opportunistic approach to conservation. However, in order to achieve maximum biodiversity gains, conservation actions need to be prioritised accordingly. In order to prioritise conservation actions and set a consistent approach to monitoring and survey work for these projects, a revised priority list and best practice guidelines (as discussed elsewhere in this review) would be beneficial.

## ***2.5 – Measure benefits of eradication***

Despite the commencement or completion of a number of eradication projects, there is a lack of baseline studies on the recovery of islands that have been subject to rodent eradication programs. However, some population surveys have been conducted for native species affected by the presence of rodents at the cessation of projects. For example, surveys on Montague island, indicated a generally positive result for seabird species recovery and nesting success (Priddel et al., 2011). Unfortunately these surveys are often conducted on an opportunistic basis and usually without the full scientific rigour of academic studies. For future studies, these should be conducted not only to measure the benefits to native species and ecological communities, but initial planning should identify any potential adverse impacts of the proposed control program e.g. trophic cascade effects through lack of integrated management of other pest species. By identifying potential risks during the planning of eradication programs, land managers and conservation organisations are likely to save resources and achieve improved project and native species outcomes.

## **2.6 – Eradicate or control other pests on islands from which rodents are to be eradicated**

Conservation approaches to islands and the removal of invasive species has generally focussed upon the multi-species approach. This approach acknowledges the unanticipated effects that may stem from the removal of one problem species that could adversely impact the ecosystem and remaining species (Griffiths, 2011). This multi-species approach is now more frequently being incorporated into planning processes for eradication and conservation efforts, for example, the current program of eradications on offshore islands in NSW (Priddel et al., 2011) where all invasive species are planned to be removed to avoid similar cascade effects. However, due to resource restrictions (funding and personnel availability) often some species are unable to be eradicated concurrently. Further, if funding is withdrawn at a critical stage during post eradication, invasive species populations may recover by taking advantage of increased resources and/or reduced competition or predation, to expand their populations (Springer, 2011).

### **Performance indicators:**

*Exotic rodents eradicated from Macquarie, Lord Howe, Mutton Bird and Montague islands, or causes of failure identified:*

Eradication programs have been completed on both Montague and Macquarie Islands. Rodents are eradicated from both islands. The eradication project for Lord Howe has been delayed due to community concerns but is projected to begin in mid 2016. Muttonbird Island in NSW has been subject to strategic baiting and surveillance since 2009, but is vulnerable to reinvasion through its re-connection to the mainland by an artificial breakwater.

*A bait with an anticoagulant toxin is registered for use for eradication of exotic rodents on islands:*

Brodifacoum based baits have been registered with the Australian Pesticide and Veterinary Medicines Authority (APVMA) for use in the control of vertebrates pests in and around manmade structures only. However, these baits are also able to be used for broader scale eradication and pest management programs under APVMA-issued minor use permits. An application to register this active agent for broad-scale use has not been submitted to date (APVMA, 2014).

*The first tranche of islands identified as high priority for eradication are introduced into state and territory planning processes:*

Eradication and management programs have been actioned for some of the priority islands identified in the Ecosure report (Ecosure, 2009) by the responsible state governments. In general, other factors (other than the Ecosure report) have determined whether a particular island has been targeted for eradication efforts. Often the decision to undertake such a project has been dictated by the availability and level of resources (funding and personnel to conduct the operations). To date, a number of high priority islands have had some form of eradication program attempted e.g. Macquarie Island, Montague Island, Brush Island and Broughton Island (Priddel et al., 2011), or are planned for the near future e.g. Lord Howe Island and South Solitary Island. However, the 2009 TAP has not been effective in



directly steering conservation efforts to high priority islands. If the 2009 TAP is revised, a new action should include focusing conservation efforts on the highest priority islands as identified in the Ecosure report (Ecosure 2009).

*All eradication plans identify and monitor pre- and post-eradication indicator native species expected to benefit from eradication of exotic rodents, and indicator native species that may be at risk from the control methods:*

As previously discussed in this review, monitoring of various eradication programs has been inconsistent. This includes pre-eradication (baseline) monitoring of native species populations and then conducting follow-up post eradication monitoring to determine any reaction to the removal of rodents or other invasive species. In many instances, this inconsistency appears to be due to a lack of either funding and/or personnel with appropriate qualifications to undertake a comprehensive survey of native species. This has lead to a number of informal or brief surveys of native fauna and flora on islands, usually post eradication. Such assessments may not represent the complete picture or sequence and therefore are likely to be of limited value for assessing the impacts of the eradication over the entire period of the project.

*All eradication plans consider the costs, benefits and risks of including other invasive species present on the island within the planning process:*

As discussed in Action 2.6, eradication programs now focus more upon multi-species eradication approaches to avoid unanticipated effects that stem from the removal of one species (Griffiths, 2011). Further information on how this indicator has been addressed can be found in Action 2.6.

## **Conclusion:**

The purpose of this action group in the original 2009 TAP was to encourage state and territory governments to progress various eradication projects on priority islands (including Lord Howe, Macquarie, Montague and Mutton Bird Islands). Additionally this action group sought to encourage capacity building across state and territory agencies in order to; plan and implement eradication projects; increase the amount of available tools for eradication; and measure the benefits to biodiversity and ecosystems that these projects and their outcomes can deliver.

The islands considered to be of highest priority in the 2009 TAP as per the offshore islands report (Ecosure, 2009) included Lord Howe Island, Macquarie Island and Muttonbird Island. Montague Island, whilst not identified in the offshore islands report, had already been identified for eradication effort in 2007 — the likely reason for its omission from the report. Eradications for the other islands have all been implemented or planned and most have been deemed successful (Bergstrom et al., 2009a, Cory et al., 2011a, Priddel et al., 2011). The exception to this is Lord Howe Island, which has been delayed due to some community concerns. At this stage, eradication efforts are expected to be commenced in 2016.

Other eradications have been conducted with some success including the Broughton group of islands, Looking Glass Island, and more recently, Boulanger and Whitlock Islands in Western Australia (Island Conservation, 2014, Island Arks Australia, 2014). However, the biodiversity benefits of most of these projects remain ambiguous as little formal monitoring of the impacts

of these projects appears to have been undertaken. Baseline monitoring to determine the impact of invasive rodent removal on native species populations and ecological communities would be beneficial to understand the efficacy of these and other projects.

Capacity and skills in eradication and invasive species management has been further developed by members of state government agencies involved in the key eradication projects such as those undertaken in NSW. While some progress has been made on the sharing of information through the publishing of journal articles and through meetings such as the Island Arks Symposium. These forums are not frequent enough to elicit a consistent sharing of knowledge and expertise. This is perhaps another case for the development of a set of national best practice management guidelines to assist with information distribution and building capacity in island eradication techniques. In relation to the accessibility of appropriate control tools for eradication projects, a brodifacoum based bait has not been registered nationally with the APVMA for broad scale use and the use of other chemical control agents for island eradications is not well established in Australia. Further examination of alternative control tool options and the registration of brodifacoum-based products for off label use would be valuable for future projects.

Other species (apart from rats and mice) are now integrated into many eradication and management plans. These species are generally eradicated concurrently or sequentially to ensure that there are no adverse impacts caused by trophic cascades or prey switching (Bergstrom et al., 2009b). However, integrated management is still not always considered due to lack of resources, or the opportunistic implementation of eradication projects.

In considering whether the aims of this action group have been met, the four islands identified as being of high priority in this action group (Macquarie, Lord Howe, Montague and Mutton Bird) have all (except Lord Howe Island) had eradication programs implemented and have proven successful. Other priority islands identified in the 2009 Ecosure report e.g. Broughton Islands and Looking Glass Island have also been subject to similar action. In many other instances state or territory governments have followed their own priorities in pursuing eradication efforts. These efforts have not necessarily been informed by the priority list set out in the Ecosure report or the intended actions of the original TAP.

The vast majority of eradication programs attempted in Australia to date have been a success (Gregory et al., 2014). A significant body of skills and capacity has also been built to carry out these eradications, but this knowledge needs to be more widely shared to develop additional capacity for future eradications.

In conclusion, while there has been some partial success in completing some of the actions above (most notably the eradications carried out on Macquarie and Montague islands), there are still many islands identified as requiring priority action that have not received any attention from state governments. Therefore a re-assessment of the national list of priority islands may be required in light of the progress made. In addition, further capacity building across jurisdictions and information and expertise sharing needs to be facilitated. A set of national best practice guidelines incorporating a new list of priority islands and the accumulated eradication knowledge acquired in the last five years, could potentially assist with this. Continued efforts are required to pursue eradication work on Lord Howe, Christmas and Norfolk Islands amongst others. There is therefore a need for the continuation of this action group but a resetting of its priorities will be necessary to help achieve these outcomes.

## **ACTION GROUP THREE OF THE 2009 TAP**

### **3.3.3 Actions to achieve sustained control**

The 2009 TAP stated:

Sustained control is the next best option to protect biodiversity values and species on islands if eradication is not feasible or cannot be immediately implemented. Timeframes under this objective for each island have therefore been listed as either 'ongoing' or 'until eradication is proposed and achieved'.

The key actions required are to first identify the available control tools for use on Australian islands and to develop best practice for their application. Second, there is a need to enhance the capacity of island residents and agencies to deliver sustained control and to monitor outcomes so that actions can be adapted as required.

3 – Actions to achieve sustained control	Priority and timeframe
3.1 Review rodent control tools registered for use in Australia	Medium priority, short term
3.2 Promote trials to develop and test best-practice sequential use of rodent control tools on islands	High priority, medium term
3.3 Train island residents or rangers as primary deliverers of sustained control on their islands	High priority, ongoing

#### ***Current state of actions***

Rodents are generally controlled as commensal and agricultural pests and for biodiversity protection on populated islands such as Lord Howe and Norfolk. However, the community and island managers conducting these operations do not usually use current best practice.

#### ***Performance indicators***

1. *A users' manual is produced to identify the technical options and their best use for purpose to sustain control of exotic rodents on islands.*

#### **Assessment of progress:**

##### ***3.1 – Review rodent control tools registered for use in Australia***

The New South Wales Department of Primary Industries has published a review of chemical control agents currently in use in Australia —'Pesticides used in the Management of Vertebrate Pests in Australia: A Review' (McLeod and Saunders, 2013). This review provides a comprehensive overview of the chemical control tools available for many invasive species such as alpha-chloralose, cholecalciferol, sodium monofluoroacetate (1080), zinc phosphide, brodifacoum, bromadiolone, coumatetralyl, difenacoum, flocoumafen, warfarin, diphacinone and difethialone. Two fumigants (chloropicrin, methyl bromide) were considered as not useful for the broad-scale eradication of rodents on islands (McLeod and Saunders, 2013). Despite this wide selection of control and eradication tools, the use of second-generation anticoagulant rodenticides such as brodifacoum and difenacoum, is considered the most effective method of rodent control (Howald et al., 2007). The use of grain bait pellets with brodifacoum as the active ingredient has dominated island eradication efforts in the past decade. Animal Control Products in New Zealand have indicated that, in the future, they intend to pursue the registration in Australia of the brodifacoum active for broad scale use and an analogous product to the Pestoff 20R rodent bait used in the Macquarie Island eradication project (Bill Simmons pers com 2014).

For the full list of rodent control tools and their usage restrictions, please refer to Table 3.1 below.

**Table 3.1- Chemical control products registered for use against rodents in Australia – Primarily extracted from McLeod and Saunders, 2013**

Active chemical	Formulation types	Usage restrictions	Potential Secondary/ Non-target impacts
<b>Alpha-chloralose</b>	Bait powder concentrate and bait blocks	<p>Registered for indoor use against mice (<i>Mus</i> sp.) by authorised personnel (McLeod and Saunders, 2013).</p> <p>This active is present in the product registered as <i>Rentokil alpha rapid rodenticide</i> on the APVMA products database.</p> <p>A single minor use permit is listed for the use of this chemical on rabbits on the APVMA's permits database (APVMA, 2014).</p>	<p>There have been reports of non-targets being killed, primarily other species of birds but also small mammals, such as hedgehogs (<i>Erinaceidae</i>) and Koi goldfish (<i>Cyprinus</i> sp.). Larger bird species and mammals, such as cats (<i>Felis catus</i>) and dogs (<i>Canis lupus familiaris</i>) that are affected tend to recover fully. The risk can be reduced by following best practice baiting procedures including the collection of non-targets affected by baits, which can then be allowed to recover under suitable conditions.</p> <p>Secondary poisoning from mice (<i>Mus</i> sp.) baiting programs is considered unlikely due to the rapid rate of detoxification. Deaths of buzzards (<i>Buteo buteo</i>) have been reported following bird control programs; however, the risk from poisoned birds is considered negligible for mammalian predators such as foxes (<i>Vulpes</i> sp.) as they would need to eat many bird carcasses including the crop contents before being affected (McLeod and Saunders, 2013).</p>
<b>Cholecalciferol</b>	Grain and block bait	<p>Control of rats (<i>Rattus</i> sp.) and mice (<i>Mus</i> sp.), particularly anticoagulant resistant individuals. It can be deployed in and around buildings and also for perimeter baiting along fence-lines around buildings (McLeod and Saunders, 2013)</p> <p>No minor use permits have been issued for this chemical in Australia (APVMA, 2014).</p>	<p>Non-target animals are at risk during a baiting campaign using this toxin. There have been dog (<i>Canis lupus familiaris</i>) deaths, while others have recovered with treatment. There are also reports of cat (<i>Felis catus</i>) deaths, although many poisoned cats have recovered as they are less likely to consume large quantities of bait.</p> <p>In terms of secondary poisoning risk, whilst cholecalciferol is relatively persistent in rats (<i>Rattus</i> sp.), the risk of secondary poisoning is considered low as this toxin is partially degraded in the intestinal tract of animals that consume it. Hence not all the cholecalciferol consumed would be bioavailable to predators or scavengers eating the affected animal (McLeod and Saunders, 2013).</p>
<b>Sodium</b>	Manufactured baits and liquid	1080 is registered in Australia for the control of	Many cases of direct poisoning of non-target domestic and native wildlife

**Table 3.1- Chemical control products registered for use against rodents in Australia – Primarily extracted from McLeod and Saunders, 2013**

Active chemical	Formulation types	Usage restrictions	Potential Secondary/ Non-target impacts
<b>monofluoroacetate (1080)</b>	concentrate (to be added to own bait substrate)	rabbits ( <i>Oryctolagus cuniculus</i> ), free-ranging dogs ( <i>Canis</i> sp.), foxes ( <i>Vulpes vulpes</i> ), feral cats ( <i>Felis catus</i> ) and pigs ( <i>Sus scrofa</i> ). It is permitted for use against rat ( <i>Rattus</i> sp.) populations in Hoop Pine plantations in Queensland under a APVMA Minor (off label) Use permit (McLeod and Saunders, 2013). The APVMA have issued seven minor use permits in total for the use of 1080 to control the Pale field rat ( <i>Rattus tunneyi</i> ) in Pine ( <i>Araucaria</i> ) plantations (APVMA, 2014).	<p>have been reported following baiting programs using 1080. Carnivores such as dingoes (<i>Canis lupus dingo</i>), free-ranging and domestic dogs (<i>C.I. familiaris</i>) and foxes are the most susceptible. Native carnivores (such as quolls) are less susceptible but may be at risk if they consume multiple baits.</p> <p>Birds are susceptible via direct consumption of baits intended for other species. However, a number of mitigation strategies have been developed that have proven effective in reducing bird mortality (change in bait type, deterrents, bait masking, burying etc).</p> <p>Invertebrates are highly susceptible to 1080 however, the impact on invertebrate populations from baiting is considered minimal and would only be of concern where endangered invertebrates or species that depend on invertebrates are present.</p> <p>Secondary poisoning effects through the consumption of poisoned individuals by other animals, is possible. The group most affected are non-native carnivores (such as domestic dogs and dingoes etc). However, there are mitigation measures that can be put in place to reduce the incidence of this (reduction in bait concentration and removal of carcasses after baiting). Other species may also be susceptible to secondary poisoning (individual deaths have been recorded in insectivorous birds) however, there is little evidence to indicate significant secondary impacts to any non-target population of organisms through secondary poisoning (McLeod and Saunders, 2013).</p>

**Table 3.1- Chemical control products registered for use against rodents in Australia – Primarily extracted from McLeod and Saunders, 2013**

Active chemical	Formulation types	Usage restrictions	Potential Secondary/ Non-target impacts
<b>Zinc phosphide</b>	Ready to use wheat grain bait or extruded pellet formulation.	<p>For control of mice populations in broad acre crops, but can also be used for control of rat populations in specified circumstances (McLeod and Saunders, 2013).</p> <p>The APVMA have granted 86 minor use permits for the use of this chemical in a number of broad scale mice and rat crop protection activities as well as for combating mouse plagues in specific regions. Some of these permits allow for the use of aerial broadcast techniques (APVMA, 2014).</p>	<p>Cases of primary poisoning of livestock, pets, and birds have been reported overseas where zinc phosphide can be applied in a range of situations. In Australia, this toxin can only be applied in-crop, so the risk for many non-targets is considerably reduced if correct procedures are followed. Cases of individual deaths in wild birds have been reported in Australia but studies into the impact on these populations are still required.</p> <p>Secondary poisoning from zinc phosphide is possible but the risk is low. The toxic action of zinc phosphide on the target animal depends on the breakdown of the compound to phosphine gas, which does not accumulate in muscle tissue and causes no secondary problems to scavengers. However, not all of the zinc phosphide consumed by the target animal is initially broken down, so scavengers can still be poisoned by amounts of the toxin if they consume the victim's stomach and intestines (Freeman et al. 1954). Compared with many other toxins, the secondary risk from zinc phosphide is considered to be low. In Australia, the species thought to be at risk from secondary poisoning are predators of mice (especially raptors), and scavengers of dead mice such as crows. The residue levels in mice after a baiting program have been investigated — an adult bird would need to consume at least nine mice to succumb to a secondary poisoning effect.</p>
<b>Brodifacoum</b>	Ready to use grain, and pellet baits, wax block, paste and bait concentrate.	<p>Registered in all states and territories for the control of introduced rats (<i>Rattus</i> sp.) and mice (<i>Mus</i> sp.), especially warfarin-resistant strains. May only be used in and around buildings, not in open areas (McLeod and Saunders, 2013).</p> <p>A number of minor use permits have been granted by the APVMA for eradication projects (APVMA, 2014).</p>	<p>Because of its toxicity and persistence in the environment, brodifacoum poses a major threat to non-target species. In Australia, this toxin is not permitted to be used in the field, and there is no information on the effects, if any on native wildlife. Reports of non-target deaths are limited to domestic animals such as cats (<i>Felis catus</i>) and dogs (<i>Canis lupus familiaris</i>) consuming baits meant for rodents (McLeod and Saunders, 2013).</p> <p>In some prominent eradication projects on Macquarie and Montague Islands, there have been recorded non-target and secondary impacts for a number of</p>

**Table 3.1- Chemical control products registered for use against rodents in Australia – Primarily extracted from McLeod and Saunders, 2013**

Active chemical	Formulation types	Usage restrictions	Potential Secondary/ Non-target impacts
			native species (these projects were conducted under the minor use permits mentioned under the 'Usage restrictions' column for this chemical) (Cory et al., 2011b, Priddel et al., 2011, Tasmanian Parks and Wildlife Service, 2013, Terauds et al., 2014).
<b>Bromadiolone</b>	Bait concentrate, contact powder, wax block, ready to use grain, and pellet bait.	<p>Registered in all states and territories for the control of introduced rats (<i>Rattus</i> sp.) and mice (<i>Mus</i> sp.), especially warfarin-resistant strains.</p> <p>May only be used in and around buildings, not in open areas (McLeod and Saunders, 2013).</p> <p>A number of minor use permits have been granted for crop perimeter baiting for mice using this product (APVMA, 2014).</p>	<p>Overseas bromadiolone is responsible for a number of non-target deaths including lagomorphs (rabbits and hares), opossums and skunks. When trialled for mouse (<i>Mus</i> sp.) control in a small crop area in Australia, no deaths in non-targets were recorded.</p> <p>Due to its persistence, bromadiolone may pose a secondary poisoning risk, particular after large field baiting programs. Also requiring further research is the impact of secondary poisoning on the populations of these predators and scavengers.</p> <p>In Australia, this toxin is currently restricted to indoor use and reports of secondary poisoning are limited to domestic animals such as cats (<i>Felis catus</i>) and dogs (<i>Canis lupus familiaris</i>) (McLeod and Saunders, 2013).</p>
<b>Coumatetralyl</b>	Wax block bait, ready to use grain or pellet bait, liquid or oil concentrate, tracking powder.	<p>Registered in all states and territories for the control of introduced rats (<i>Rattus</i> sp.) and mice (<i>Mus</i> sp.) although unlikely to control warfarin resistant mice effectively. Only to be used in and around buildings for mice, however, can be used against rats in certain crops (McLeod and Saunders, 2013).</p> <p>The Lord Howe island board currently hold a minor use permit to use this poison in bait stations (APVMA, 2014).</p>	Direct risk from secondary poisoning to predatory and scavenging birds and mammals is considered low however, it may indirectly limit food supply for some specialist predators. Mammal deaths have been reported under laboratory conditions, but not for birds (McLeod and Saunders, 2013).



**Table 3.1- Chemical control products registered for use against rodents in Australia – Primarily extracted from McLeod and Saunders, 2013**

Active chemical	Formulation types	Usage restrictions	Potential Secondary/ Non-target impacts
<b>Difenacoum</b>	Ready to use grain, and pellet baits, wax block, gel, paste and liquid concentrate.	Registered in all states and territories for the control of introduced rats ( <i>Rattus</i> sp.) and mice ( <i>Mus</i> sp.). Effective against rats resistant to other anticoagulants, but not totally effective against resistant mice. May only be used in and around buildings, not in open areas (McLeod and Saunders, 2013).  No minor use permits have been issued for this chemical in Australia (APVMA, 2014).	Although there are no reports in the literature, difenacoum would have a similar potential to kill non-targets species as other anticoagulants.  Sub-lethal haemorrhaging was found in owls after feeding on poisoned rats ( <i>Rattus</i> sp.) in laboratory trials. Several species of birds have died in zoos after consuming poisoned mice ( <i>Mus</i> sp.) or cockroaches. There are reports of residues in wild avian raptors and this toxin has been implicated in a small number of raptor deaths in the field. Residues have also been found in mammal predators as well as insectivores such as hedgehogs. Although no deaths have been recorded, some correlation between the fitness of some species of mustelids and the concentration of the anticoagulant residue in these animals has been found (McLeod and Saunders, 2013).
<b>Flocoumafen</b>	Ready to use grain and pellet baits, wax block and bait concentrate	Registered in all states and territories for the control of introduced rats ( <i>Rattus</i> sp.) and mice ( <i>Mus</i> sp.), especially warfarin-resistant strains. May only be used in and around buildings, not in open areas (McLeod and Saunders, 2013).  No minor use permits have been issued for this chemical in Australia (APVMA, 2014).	Non-target mammal species are more at risk than birds from baiting programs however, this bait could still be problematic to birds if bait is used as a major food source over several days (McLeod and Saunders, 2013).
<b>Warfarin</b>	Bait concentrate, ready to use pellet baits, gel and tracking powder.	Registered in all states and territories for the control of introduced rats ( <i>Rattus</i> sp.) and mice ( <i>Mus</i> sp.) (McLeod and Saunders, 2013).	Warfarin is considered safe for non-target species as it is metabolised comparatively quickly and repeated doses over several days are required for mortality.  The secondary risk particularly under field use is considered very slight especially when compared to other anticoagulants (McLeod and Saunders, 2013).
<b>Diphacinone</b>	Bait concentrate and ready to use nugget bait.	Registered in all states and territories for the control of mice ( <i>Mus</i> sp.) only. May only be used in and around buildings, not in open areas	There are no published reports of non-target deaths due to this toxin in Australia, although its use is restricted. In the USA and New Zealand, diphacinone baits are used for broadcast field applications.

**Table 3.1- Chemical control products registered for use against rodents in Australia – Primarily extracted from McLeod and Saunders, 2013**

Active chemical	Formulation types	Usage restrictions	Potential Secondary/ Non-target impacts
		<p>(McLeod and Saunders, 2013).</p> <p>No minor use permits have been issued for this chemical in Australia (APVMA, 2014).</p>	<p>The secondary poisoning risk is considered very low when compared to other anticoagulants. Raptors are thought to be susceptible and owls have died of haemorrhaging after feeding on poisoned rats (<i>Rattus</i> sp.) in laboratory trials. Mink (<i>Mustela</i> sp.) and dogs (<i>Canis lupus familiaris</i>) have died after being feed diphacinone poisoned nutria (<i>Myocastor coypus</i>) which may indicate the possibility of a secondary poisoning risk to mammalian predators under the correct circumstances (McLeod and Saunders, 2013).</p>
<b>Difethialone</b>	Grain and block baits (ready to use).	<p>Registered in all states and territories for the control of introduced rats (<i>Rattus</i> sp.) and mice (<i>Mus</i> sp.), especially warfarin-resistant strains. May only be used in and around buildings, not in open areas (McLeod and Saunders, 2013).</p> <p>No minor use permits have been issued for this chemical in Australia (APVMA, 2014)</p>	<p>Birds are relatively susceptible to this toxin, but there are no reports of deaths in the literature.</p> <p>From residue studies, this toxin is thought to be a relatively low risk for secondary poisoning and no reports of mortality have been recorded in Australia (McLeod and Saunders, 2013).</p>

### **3.2 – Promote trials to develop and test best-practice sequential use of rodent control tools on islands**

A great deal of experience has been accumulated on this subject due to the implementation of a number of eradication projects on Australian islands including Macquarie and Montague Islands (Priddel et al., 2011). This experience could inform future eradication strategies and actions in relation to effective procedures and sequencing of rodent control tools and methods. However, despite this accumulated experience, no formal trials to determine best practice methods for the different rodent control tools have been conducted.

In terms of sustained control, the majority of eradication attempts in Australia have been successful (Gregory et al., 2014), which means that sustained control efforts have been limited. As such, examples of effective sustained control programs are difficult to find and demonstrate. Rodent control efforts in the Norfolk Island National Park are one example of a sustained control program. Both ship rats and pacific rats, (but predominantly ship rats (*Rattus rattus*) are believed to have impacts on the native fauna of the island through predation. Species impacted include the golden whistler (*Pachycephala pectoralis xanthoprocta*), the scarlet robin (*Petroica multicolor multicolor*), the Norfolk Island green parrot (*Cyanoramphus cookii*), nesting seabirds such as the Kermadec petrel (*Pterodroma neglecta neglecta*), a number of endemic reptiles, and invertebrate species such as land snails. Additionally, rodents are a threat to plant species such as *Achyranthes arborescens*, *Melicope littoralis*, *Meryta latifolia* and *Ungeria floribunda* due to their consumption of the fruits and seed (Director of National Parks, 2010).

The control of ship rats (*Rattus rattus*) (believed to have been first introduced to the island in 1942 via a shipwreck) and pacific rats (*Rattus exulans*) (believed to have already been present from previous visits by visiting Polynesian people) on Norfolk Island has been underway since 2010. This control has been focussed on the eradication of both of these species from the National Park and the surrounding forestry areas (Director of National Parks, 2010). The baiting operations have involved the use of bait stations set along baiting lines within the National Park and maintained at regular intervals. Currently, it is not feasible to attempt an island-wide eradication of rodents on Norfolk Island. Because the national park only exists as a small part of a populated island, any eradication of this scale would require significant community consultation and support in order for it to be a success.

This aim of this action was to encourage best practice use of rodent control tools on islands where eradication is not feasible, and where sustained control is the most effective option to reduce the impacts of these pests. As most of the work in Australia has been focussed upon the eradication of rodents from islands, examples of sustained control are limited. However, the example of sustained control given above, and experiences in the use of various control tools during eradication projects, may be used to inform future efforts. As mentioned previously, there is a need for a compilation of this accumulated experience into national best practice guidelines to allow sharing of knowledge across jurisdictions in a single comprehensive package.

### **3.3 – Train island residents or rangers as primary deliverers of sustained control on their islands**

The training of island residents, in particular traditional owner groups, has advanced markedly in the past decade. This has been assisted by the training provided under the Australian Government's Working on Country program to island residents and indigenous land owners to manage and monitor invasive species populations on their islands. One example of such training in the control of invasive species is the Li-Anthawirriyarra Sea Rangers and Yanyuwa Traditional Owners groups, who are responsible for the management of the Sir Edward Pellew Islands and the riverine and coastal areas of the southwest Gulf of Carpentaria in the Northern Territory. This area of management includes eight large islands and more than 50 small islets and reefs (Department of the Environment, 2014b).

In 2011, the Yanyuwa Traditional Owners and Li-Anthawirriyarra Sea Rangers commenced a cat control project on West Island to restore native flora and fauna on the 130 square kilometre island. In three consecutive years since 2011, this baiting program has distributed over 5000 Eradicat® 1080 cat baits across West Island annually via both aerial and ground distribution methods. Transects and camera traps are being used to monitor cat densities and their movements around the island. In 2011, West Island encountered a season of exceptionally high rainfall and initially the baiting produced little impact on the cat population. The 2012 baiting season, however, resulted in a significant decrease in cat numbers across most areas of the island, with follow-up baiting being undertaken in 2013. This 'knockdown' phase of the eradication programme has been declared a success and will now be followed up by a monitoring and hunting phase using intense trapping and cat detector dogs to remove the remaining cat population (Island Arks Australia, 2014). Following the reduction of the cat population on West Island, there has been increase in the population of delicate mice (*Pseudomys delicatulus*) and water rats (*Hydromys chrysogaster*) detected on West Island after a long absence from the island. This program has allowed native rangers to learn the tools and techniques which are useful in the control and monitoring of invasive species. This knowledge and experience is expected to assist them in future efforts for recovering native ecosystems.

Another example of effective invasive species control by island residents under the Working on Country programme is control efforts undertaken by the Bardi Jawi Rangers, based at One Arm Point in the Dampier Peninsula in Western Australia, (Department of the Environment, 2014b). The rangers, in cooperation with the Western Australian Parks and Wildlife Department and the Invasive Animals Cooperative Research Centre, undertook a survey of the ship rat (*Rattus rattus*) population on Sunday Island/Iwany to determine its extent and the need for a control programme. This survey discovered that ship rats were entirely absent from Sunday Island (although they are believed to have been present historically), however, a significant population of native mosaic-tailed rats (*Melomys cervinipes*) were present. It was proposed that the native rats may have extirpated the invasive ship rats from the island through competition (Island Arks Australia, 2014). Whilst this activity has not involved a control programme for ship rats at this stage, the survey activity and the previous invasive species work undertaken by the rangers, demonstrates an understanding of introduced rodent impacts on native species. It also demonstrates the willingness of land managers to seek expert training in effective eradication programs i.e. the necessary tools and techniques.

On Mer Island (Torres Strait), residents have also been involved in the control of invasive species through eradication programs from December 2009 to 31 December 2012 under the supervision of the University of Queensland, and with funding from the Australian Government Caring for Our Country program. This eradication program aimed to eradicate ship rats (*Rattus rattus*) and house mice (*Mus musculus*) from Mer Island. The project used bait stations strategically placed around settled or disturbed areas of the island — these areas were determined to have the highest density of the non-native rat species, with the native grassland melomys (*Melomys burtoni*) extirpating the invasive species from the less disturbed natural habitat. In total, the island was subject to nine rounds of baiting over the four year project, with the eradication deemed a preliminary success at the end of this period.

During the course of the Mer Island project, the staff were assisted by both members of the Torres Strait Island Regional Council and the Mer Island rangers; all of whom were involved in the baiting and received training in rodent pest biology and management from the project team (Leung, 2013). This training and exposure should assist these staff and rangers in conducting their own management actions for invasive species, including invasive rodents, in the future.

A final example of island residents contributing to the sustained control of invasive species on islands is the control of ship rats and mice by residents of Lord Howe Island. These control efforts have taken place since the 1950s in and around both the settled areas of this island and in the now-closed kentia palm plantations on the island. The baits used are a mixture of warfarin and brodifacoum dispersed throughout approximately 1000 bait stations across the palm plantation, the palm nursery and the main settlement. All efforts involve island residents who are engaged by either the Lord Howe Island Board or on a volunteer basis. These participants have been trained to distribute and maintain bait stations to control invasive rodents over a broad area. These volunteers are a good example of local people being utilised to deliver a control program for invasive rodent species.

## **Performance indicators**

*A users' manual is produced to identify the technical options and their best use for purpose to sustain control of exotic rodents on islands*

This performance indicator focuses on the development of a technical best practice manual for the control of rodents using toxic baits and other control tools on islands — this manual is yet to be produced. The current process for developing a new eradication project or pest control plan, including the selection of the appropriate control techniques and their application, is to consult the current literature and expert opinions in order to construct a draft plan. By using both the previous experience available in the literature, and consulting with island eradication experts, control procedures, and techniques, it has been possible to draft effective plans in the past to carry out conservation projects of this kind.

A good example of this is the Macquarie Island Eradication Plan which was drafted by the then Tasmanian Department of Primary Industries and Water and revised in consultation with Dr. Andrew Burbidge (WA Threatened Species Scientific Committee) and a number of other advisors from the Tasmania Parks and Wildlife Service, Australian Antarctic Division and the Invasive Animals CRC (Tasmanian Parks and Wildlife Service, 2010a).

This process has proven to be a sound way to produce a plan for the eradication or control of an invasive species and can ultimately be very successful (as was the case with Macquarie Island). However, in order to ensure that all technical and logistical options for eradication or control are considered, it would be advisable to consult as widely as possible and to incorporate ideas and techniques from previous projects, where applicable. Therefore, while eradication and control projects can be developed through expert consultation alone, a resource such as a manual or summary document detailing the control and eradication techniques currently in use and the different situations in which they are effective (and the literature to demonstrate this) could be a useful resource for land managers in addition to expert advice. This could act as a sound starting point for the development of a new eradication or control plan. A good example of such a resource that is currently in use is the '*Resource Kit for Rodent and Cat Eradication*' produced by the Pacific Islands Initiative and published online (Pacific Islands Initiative, 2011). This extensive resource deals with the complete process of setting up and organising, implementing and evaluating a control or eradication project.

In the context of chemical control agents, the information on which agents are registered and may be used for the eradication and control of invasive rodent species is available from many different sources. These include the NSW DPI publication '*Pesticides used in the Management of Vertebrate Pests in Australia: A Review*' (McLeod and Saunders, 2013) and the APVMA's databases of registered chemicals and permits. While these are useful resources for land managers and project leaders designing control programs, they do not identify the best practice use of these chemicals in the context of broad-scale control or eradication projects for rodents. Additionally, there are a number of different options for the application of toxic baits such as brodifacoum, difenocoum and bromadiolone (which are the most proven and prevalent baits used in eradication and control projects to date) when controlling rodents in differing situations and these methods have been applied across a number of different projects. These include grain pellets distributed by either hand or mechanical means (e.g. Macquarie Island and Montague Island) and wax blocks; bait stations which are more weather resistant than the standard grain pellets and are designed to exclude non-target animals of a certain size from taking the contents (e.g. Mer Island and Norfolk Island); and paste and other soft baits, which have generally only been utilised in domestic situations due to a lack of durability in outdoor applications (APVMA, 2014). These application methods have been discussed in the literature to a degree, e.g. (Howald et al., 2007), but the full breadth of information on this subject, and the practical approaches to applying the techniques, have not been condensed into a single resource of the kind proposed in this performance indicator.

Therefore, information on available toxic baits and the different methods of their application for conservation projects is available and has been discussed in the literature on this subject. What has not been compiled into a concise resource to date is the accumulated knowledge and expertise of land managers and conservationists with field experience on what baits and baiting strategies are best implemented in differing circumstances and the best practice use of these tools and techniques. A resource such as this would allow land managers to maximise the benefits to islands upon which these tools are used to control or eradicate invasive species.

## **Conclusion**

A review of toxins for vertebrate pests has been produced by the NSW Department of Primary industries (DPI) (McLeod and Saunders, 2013). Although this document is not specific to

rodents, it contains information on all the chemical control agents currently registered for vertebrate pest control (see Table 3.1 for excerpts from this paper relating to rodents).

While no trials to test for best practice use of the above toxins have been conducted, accumulated experience and expertise during the various attempted eradication projects over the past five years exists. It would be useful to capture this accumulated knowledge into a best practice guidelines document as proposed under Action 1.3 of this review.

Training of island residents as rangers and land managers has progressed through the Working on Country program amongst other examples. Continued support by the Working on Country program and other programs and initiatives of this sort would be beneficial to island communities to continue to increase capacity of island residents to manage their island's environment and achieve sustained control of rodent pests.

Looking forward, if a revised Threat Abatement Plan is written, it should be possible to incorporate the information from the NSW DPI review of chemical control tools (McLeod and Saunders, 2013) and the accumulated experience from various eradication projects in the best use of these tools into the best practice guidelines document as proposed in Action 1.3 of the 2009 TAP. The successful Working on Country program has demonstrated the value in training island residents to become land managers and it may be of benefit to encourage the uptake and expansion of the island residents training in other areas, including rodent eradication. These measures should contribute to maintaining an effective level of expertise in sustained control.

## ACTION GROUP FOUR OF THE 2009 TAP

### 3.3.4 Actions to prevent invasion or reinvasion

The 2009 TAP stated;

There is a need to apply appropriate management to reduce the risks of invasion or reinvasion of islands by exotic rodents and to detect and deal with any failures of this management. In the absence of data on these risks, costs, and consequences, it is unclear how to intervene in an optimal way. The actions in this objective aim to develop appropriate procedures that can be applied and monitored in ways to clarify best-practice border management and responses to incursions on islands with different risk and consequence profiles.

Actions to prevent invasion or re-invasion	Priority and timeframe
4.1 Develop generic contingency plans for reaction to any new rodent invasions	High priority, short term
4.2 Apply quarantine systems on rodent-free islands and where eradication is achieved	High priority, ongoing
4.3 Develop island-specific contingency capabilities for islands at high risk of invasion	High priority, short term
4.4 Reduce risk of rodents gaining access to key vessels at key ports	Medium priority, medium term
4.5 Identify and reduce the frequency of rodent infestation on key Australian vessels, i.e. those regularly berthing on priority islands	Medium priority, medium term
4.6 Survey rodent species and prevalence on foreign boats that present risks to Australian islands	Medium priority, short term
4.7 Develop and test on-island prophylactic (e.g. permanent bait stations at high-risk sites) and reactive (e.g. surveillance and prompt control after any detection of rodents) strategies to detect and deal with incursions	High priority, short term and ongoing
4.8 Develop fast response capabilities to react to shipwrecks on priority islands	High priority, short term
4.9 Actively involve island residents and ship owners in the management of incursion risks	High priority, long term

### Current state of actions

There are overseas and Australian models for order management actions, but all are still works in progress. For example, Lord Howe and Christmas Islands have quarantine strategies that include rodents (which would become critical if the extant rodents were eradicated).

The managers of Barrow Island (free of exotic rodents) are developing a formal detection and search protocol for invasive species to reduce risks and improve responses. This is as a consequence of the planned influx of shipping and aircraft to service the new oil and gas facilities being established on the island.

The use of genetic tools to identify individual animals, their parentage, discrete populations, as well as a mark-recapture method to assess population size, allows managers to quantify some aspects of invasion risk to direct and optimise management options.

### Performance indicators

- *Contingency quarantine and response plans for all islands are in place as part of feasibility studies or quarantine plans for high priority rodent-free islands.*



- *Infestation rates on key Australian and foreign vessels are measured.*

## **Assessment of Progress**

### ***4.1 – Develop generic contingency plans for reaction to any new rodent invasions***

Although a number of individual island eradication projects have produced contingency plans for invasion or reinvasion of islands by rodents, there is no indication in the literature that generic plans have been created to act as a template for responses to new rodent invasions. Specific contingencies for rodent invasions have been, or will be, incorporated into broader quarantine plans for individual islands such as Barrow Island, Lord Howe Island and Macquarie Island. Some details of these projects and the measures that have been put in place to combat rodent incursions are examined below. These show that there is sufficient prior experience in various institutions in Australia to produce effective measures to prevent the invasion or reinvasion of priority islands by rodents.

The Macquarie Island Eradication Project to control ship rats, house mice and rabbits, ran between 2010 and 2014, with the island being declared pest free in April 2014. Since the conclusion of the project, the negotiations for a biosecurity plan for the island have been underway between the Tasmanian Parks and Wildlife Service and the Australian Antarctic Division (AAD). This document aims to formalise the procedures currently in place to regulate the movement of cargo and visitors on and off the island and the ships used to transport this cargo to the island. This plan will manage the potential biosecurity risks these activities may pose to the islands ecosystem, such as the introduction or reintroduction of invasive species to the island. The plan will also likely include measures to contain and eradicate any new incursion onto the island by pest animals or weeds, however, these details are still under negotiation.

Currently, the AAD has a number of standard operating procedures for biosecurity screening and processing in place. These procedures act to control the incursion risks in place of a specific plan for the island. However, the goal of producing a biosecurity plan tailored to the island and its circumstances is still considered to be of high importance to both the Tasmanian Parks and Wildlife Service and the AAD—the current procedures deal only with preventing the introduction of invasive species to the island through the movement of materials and personnel to the island. It does not detail any contingencies in the event of an incursion of a pest species (such as rats or mice). Once this biosecurity plan is published, it could act as a useful template for other islands wishing to put into place a similar plan with contingencies dealing with pest animal invasion.

Another example of contingency planning for reinvasion is the quarantine system on Barrow Island, which lies off the coast of Western Australia's Pilbara region and has long been recognised as one of the most significant refuges in this state for a selection of native flora and fauna.

In 1964 the energy company Chevron Australia began oil drilling operations on the island and its surrounds and has continued this activity for over 50 years. The latest project approval associated with the island and Chevron Australia, is the Gorgon LNG project, one of the largest liquid natural gas extraction projects in the world, and the largest of its type in Australia. As part of its compliance with approval conditions set by both the state government of Western Australia and the Australian Government, strict quarantine

measures have been put in place by Chevron to reduce the risk of the introduction of non-indigenous species to the island through its activities (Chevron Australia, 2010).

This quarantine system which incorporates inspections of all vessels, personnel and cargo coming onto the island, also includes a surveillance and monitoring system to detect any non-indigenous species. Ship rats are considered to be a high risk species and are specifically targeted under the system using techniques such as hair traps, baited chew cards, ink pad tracks, cage traps and remote camera traps, as well as surveys by qualified personnel. These surveillance methods also target specific areas on the island that are the most likely to act as the point of entry for an incursion, such as the ports and barge landing sites, the main settlement and the gas plant. This helps to concentrate the surveillance resources to the areas of greatest risk. The purpose of these multiple surveillance techniques is to allow for the rapid detection of any non-indigenous species and allow effective eradication measures to be applied while the population of the invasive species is still low (Jarrad et al., 2011a). This surveillance system therefore incorporates a contingency measure for the eradication of an invasive species. It also aims to reduce not only the cost but to reduce the non-target and secondary impacts from any eradication effort upon native fauna by catching the incursion in its early stages (Greenslade et al., 2013b).

The quarantine and surveillance system on Barrow Island has been highly successful. Since the eradication of rats from the island in 1991 (Morris 2011), there have been no major incursions by rats or other species despite the high levels of human traffic on and off the island (Moore et al., 2010).

As an example of a generic contingency plan to prevent invasion or reinvasion, the Secretariat of the Pacific Regional Environment Programme based in Samoa, has developed the document '*Guidelines for Invasive Species Management in the Pacific; A Pacific strategy for managing pests, weeds and other invasive species*'. This document contains a guide to developing a biosecurity plan to 'Prevent the spread of invasive species across international or internal borders'. One of the objectives under this section of the guidelines is to 'develop and implement model contingency plans for managing different kinds of newly arrived pest species and carry out field trials' (Secretariat of the Pacific Regional Environment Programme, 2009). While the guidelines do not detail what the contingency plan should include, it does highlight the importance of such a contingency plan as a component in a successful biosecurity plan to reduce the risk of an invasive species establishing on an island.

Another example from the same organisation is the Pacific Islands Initiative '*Resource Kit for Rodent and Cat Eradication*' (Pacific Islands Initiative, 2011). This online resource provides specific templates and guidelines for setting up and implementing eradication and control projects for rodents. It includes suggestions on how to incorporate monitoring, surveillance and contingency measures to detect and deal with reinvasions should they occur.

Not all of the plans above include measures to be taken in the event of a new incursion of rodents onto an island or a reinvasion. However, for the plans that do include measures (such as the quarantine system in place for Barrow Island), it is considered a key component in preventing the establishment or re-establishment of pest species (such as rodents) on an island. Some of these plans also include details of many other biosecurity and quarantine measures to prevent invasions occurring. While these biosecurity and

quarantine measures are not generic in that they apply to specific islands and their circumstances, they provide good examples of strategies that can be adopted by other land managers wishing to establish similar plans.

Barrow Island in particular, is an excellent example of good biosecurity planning. Barrow Island receives far more boat traffic and therefore human influence than many other islands (such as Macquarie Island) due to the presence of the Gorgon LNG project — yet it has stayed almost pest free (Moore et al., 2010). While not all land managers will have access to the same level of resources as those on Barrow Island, most other islands would not receive the same level of human visitation that Barrow Island does. Therefore, it could be expected that the biosecurity model employed on this island could be successfully modified and deployed to suit the circumstances of other islands.

#### ***4.2 – Apply quarantine systems on rodent-free islands and where eradication is achieved***

As discussed against Action 4.1 above, Barrow Island is probably the best domestic example of this strategy. Following on from the eradication of rodents from Barrow Island and the surrounding islands in 1991 (Morris, 2011), Barrow Island has been subject to strict quarantine conditions and the ongoing quarantine program, including monitoring, surveillance and targeted control measures. This has been very successful in maintaining the pest free status of this island over the past 23 years (Jarrad et al., 2011a, Moore et al., 2010, Morris, 2011)

Macquarie Island, which was declared pest free on 7 April 2014, has not yet implemented an island specific formal biosecurity plan for passengers and cargo ships arriving at the island. However, negotiations are underway between the Tasmanian Parks and Wildlife Service and the Australian Antarctic Division for the implementation of this plan. Currently, the island is protected by measures from the Australian Antarctic Divisions' Standard Operating Procedures for biosecurity and quarantine on sub-Antarctic islands. These procedures require that all cargo being transported to Macquarie Island undergo a biosecurity screening process to pick up pests such as rodents prior to the cargo being shipped. All cargo, equipment and personnel arriving on Macquarie Island are similarly subject to quarantine procedures on arrival (Australian Antarctic Division, 2012).

These examples show that the experience and expertise exist to be able to apply effective quarantine programs to priority islands that are either pest free or where future eradication programs are planned.

#### ***4.3 – Develop island-specific contingency capabilities for islands at high risk of invasion***

As discussed earlier, Barrow Island is perhaps the best example of a working contingency system for islands on which rodents have been eradicated. These same measures could be applied to islands still free of invasive species. Should a new incursion of rodents be detected on the island, contingency measures would include the application of bait stations and more intensive monitoring and surveillance of the affected area. While this system has not been tested significantly by a serious invasion by rodents, Barrow Island is at a high

risk of reinvasion due to the large amount of human and commercial traffic. Despite this high risk, the stringent quarantine measures to prevent new incursions of rodents have been successful over the past 23 years with the island remaining pest free. As a system, the Barrow Island quarantine system is an example worth noting for future projects (Moore et al., 2010, Jarrad et al., 2011a).

Macquarie Island was declared pest free on 7 April 2014 after a concerted and significant eradication program undertaken by Tasmania Parks and Wildlife and the Australian Antarctic Division, with input from subject matter experts. This pest free status was achieved, in part, due to the efforts of the monitoring and hunting teams involved in searching for surviving rodents following the baiting phase of the eradication. This phase was conducted by using specially trained dog teams to patrol the island and was complemented by spotlighting and trapping techniques for two years after the completion of the baiting phase. If evidence of rodents were to be found, under the Macquarie Island project's monitoring plan, control techniques such as bait stations and burrow fumigation would be used to eradicate the remnant population of rodents (Tasmanian Parks and Wildlife Service, 2013, Tasmanian Parks and Wildlife Service, 2010b). While this follow-up phase of the eradication project is not expressly a contingency to prevent reinvasion, the techniques and measures used during this eradication phase could be useful in future operations on Macquarie Island if a new rodent invasion was detected. Additionally, these operations could be used as a model for similar purposes on other islands to prevent invasion/ reinvasion, rather than as a confirmation of eradication success.

Lord Howe Island is an example of a location with quarantine measures in place to prevent new invasions at the border, but no formal contingency to deal with new incursions. The 2009 draft rodent eradication plan, awaiting implementation in 2016, addresses the subject of improving the existing quarantine system on the island to ensure that the risk of reinvasion is minimised post eradication. This does not include contingency measures to deal with the reinvasion of rodents. However, island residents are already experienced in baiting operations due to their involvement in ongoing control operations around the main settlement (Lord Howe Island Board, 2009). In addition, as in the above example of Macquarie Island, the process of undertaking the eradication project on Lord Howe Island may help to develop capabilities of island residents and rangers to carry out contingency measures in the future.

All of the above islands have quarantine measures in place to prevent invasions (although Lord Howe currently has rodents present). However, none have formal contingency plans in place in the event of an invasion of a new pest species — the exception to this is Barrow Island, which due to its strict quarantine regime, has not had its contingency plans significantly tested and therefore could not be said to have developed significant abilities in executing a contingency plan. The quarantine plan on Barrow Island has however, been very successful in preventing the reinvasion of rodents to this island for over two decades. Therefore, this plan and the contingencies attached to it should be looked upon as an example of best practice in this area.

Despite this lack of practical experience in delivering contingency plans, the knowledge gained in the eradication projects on islands such as Macquarie and Barrow should allow contingency plans to be developed. In particular, the experience gained from the follow-up monitoring and hunting activities for rodent pests on Macquarie Island means that enough experience exists in monitoring, surveillance and targeted control techniques to design appropriate contingency plans for other high priority islands in the future.

#### **4.4 – Reduce risk of rodents gaining access to key vessels at key ports**

Efforts to detect and control rodents on vessels that come into contact with priority offshore islands can be seen in the quarantine measures in place on Macquarie Island, Lord Howe Island and Barrow Island.

Lord Howe Island has a range of quarantine measures in place in relation to the freight of cargo to the island. These include the inspection of cargo upon arrival at the island and the treatment and disposal of items deemed to be a risk to the island's biosecurity. The quarantine measures also include an arrangement with the ship the 'MV Island Trader' and its associated freight business, to undertake rodent control on the vessel and at its home dock at Port Macquarie (Landos, 2003, Lord Howe Island Board, 2009).

Macquarie Island is currently protected from the invasion of pest species such as rodents by the biosecurity measures put in place by the Australian Antarctic Division (AAD) for all ships and cargo bound for the island. These measures require that all cargo bound for Macquarie Island be inspected by AAD's Supply Services Group for biosecurity risks before departure and if necessary, treated for pests by fumigation or baiting (Australian Antarctic Division, 2012). This action prevents access to rodent pests at the port of origin and prevents the reinvasion of Macquarie Island by rodents.

Barrow Island has targeted quarantine and biosecurity measures at key points on the island that receive the highest volume of human traffic, and therefore pose the highest risk of reinvasion by rodents. These include the Gorgon Gas plant, the current settlement on the island, the landing site for barges transporting equipment to the island, and the directional drilling facility. By focussing the monitoring and surveillance activities on these areas, the quarantine system on Barrow Island is able to rapidly detect the presence of rodents and apply appropriate control measures (Chevron Australia, 2010). Additionally shipments being sent to the island and the facilities that house them on the mainland undergo similar inspections and targeted rodent control efforts to reduce the likelihood of rodents using these shipments as a pathway to the island.

The above examples highlight measures put in place to prevent the movement of pests on vessels to priority islands. These measures directly align with the action as stated above. The measures of inspecting and treating cargo before departure, such as those for Barrow Island and Macquarie Island, also achieve this purpose, as the vessels are effectively made rodent and pest free before they depart. Similarly, the actions taken for the protection of Lord Howe Island by requiring rodent control on the vessel the 'Island Trader' are a good practical example of limiting rodent access to a vessel through chemical control. However, arrangements of this sort might be more difficult to maintain where multiple vessels are involved, and only irregularly used in shipping to protected islands — this would increase the difficulty of ensuring compliance with the pest control measures. Finally, the targeted quarantine surveillance for rodents and other pests on Barrow Island could be used as an example of how to monitor key ports for the presence of pest species and apply targeted control, and therefore reduce rodent access to vessels at these ports.

#### ***4.5 – Identify and reduce the frequency of rodent infestation on key Australian vessels, i.e. those regularly berthing on priority islands***

A good example of reducing rodent infestations on key vessels can be seen in the quarantine measures in place for Lord Howe Island. These include the arrangement with the vessel the 'MV Island Trader' to undertake rodent control on the vessel due to its frequent visits to Lord Howe Island (Landos, 2003).

As covered in depth against the action points above, Macquarie Island is currently subject to the standard operating procedures put in place by AAD for quarantine and biosecurity on all vessels/personnel/cargo moving on and off sub-Antarctic islands. This includes the inspection of all cargo and vessels making the journey to the island and the application of control measures for rodents such as fumigation and baiting (Australian Antarctic Division, 2012). These measures are applied to all vessels and prevent rodent infestations on vessels that will be berthing on the island.

In the quarantine plan for Barrow Island, Chevron Australia have identified cargo and equipment bound for the island as one of the risk items to receive inspection before its arrival on the island (Chevron Australia, 2010). Although the quarantine plan does not expressly identify the inspection and treatment of vessels it is likely that, similar to the example of Macquarie Island, by the act of inspecting the cargo of a ship to berth on Barrow Island, a rodent infestation on these vessels could be easily identified and eradicated.

This action has been directly addressed in examples such as Lord Howe Island above where the direct treatment of key vessels has been part of the quarantine policy for this island. In other examples, the focus of the biosecurity efforts has been to inspect and treat individual cargo being sent to an island for infestations of rodents, as on Barrow Island, and each strategy is relevant to the islands utilising them. Applying the lessons learnt from these strategies in the future will be essential to successfully protect islands from potential re-invasion. The continued use of these models should also allow for their refinement. For islands that experience limited and well controlled boat traffic such as Lord Howe Island, it is likely that maintaining rodent free vessels will be the most practical option for other similar islands in future as it is not feasible in these situations to commit a large amount of resources to on-ground quarantine. However, for islands with a high volume of boat traffic such as Barrow Island (Morris, 2011), the policy of quarantine and surveillance efforts coupled with the inspection of individual cargo prior to departure to an island but also upon arrival, rather than maintaining rodent free vessels, seems to be more practical. This tactic potentially provides a better solution for highly trafficked islands, as it allows biosecurity screening efforts to be focussed on the areas of greatest risk and achieves a similar outcome to the screening of particular vessels.

#### ***4.6 – Survey rodent species and prevalence on foreign boats that present risks to Australian islands***

In all of the quarantine measures identified in the action groups above, most of the surveillance and detection efforts appear to be focussed on entry points on islands (Barrow Island, Lord Howe Island), or focused on cargo to be transported to these islands (Macquarie Island, Lord Howe Island and Barrow Island). There is no mention of international vessels undergoing rodent surveys in relation to protecting specific islands in

Australia, although the Department of Agriculture and Water Resources does inspect international vessels for the protection of Australia's biosecurity under the *Quarantine Act 1908* (Note: this Act will be superseded in July 2016 by the *Biosecurity Act 2015*). The *Quarantine Act 1908* requires that all international vessels entering Australia be free of rodent infestations and have a Ship Sanitation Certificate under the *International Health Regulations (2005)* (Australian Department of Agriculture, 2014).

Considering the quarantine measures in place on a number of Australian islands, the experience that exists in surveillance, monitoring and eradication of rodents on islands elsewhere, and the inspection of vessels for rodents by the Department of Agriculture and Water Resources, the inspection of international vessels seems to not always be a priority action in biosecurity plans (apart from the general inspection of all vessels and cargo upon arrival at key islands). This seems to be an oversight. However, as there are many international vessels that visit islands such as Christmas, Macquarie, Cocos Keeling, Norfolk, Lord Howe, as well as islands in the Torres Strait that could potentially carry rodents to these islands. There is the potential to incorporate environmental drivers into the inspections of vessels undertaken by the Department of Agriculture and Water Resources in the future. This would help to ensure that biosecurity risks posed to Australian islands by international vessels are minimised as much as possible.

#### **4.7 – Develop and test on-island prophylactic (e.g. permanent bait stations at high-risk sites) and reactive (e.g. surveillance and prompt control after any detection of rodents) strategies to detect and deal with incursions**

The use of permanent bait stations is mentioned in the implementation of a number of eradication and quarantine and surveillance projects, most notably the Barrow island eradication and quarantine project (Morris, 2011) and the eradication of ship rats from Mer Island in the Torres Strait (Leung, 2013). More reactive strategies that have been developed can be seen in the eradication of ship rats, mice and rabbits from Macquarie Island (Tasmanian Parks and Wildlife Service, 2013, Tasmanian Parks and Wildlife Service, 2010b) and the quarantine system on Barrow Island (Chevron Australia, 2010, Jarrad et al., 2011a)

The eradication project on Mer Island in particular, utilised permanent bait stations to control ship rats in and around dwellings on the island. These were used in a targeted and reactive manner, in that dwellings that reported a recurrence of rodent infestation were targeted for repeated baiting rounds. This strategy has proven successful to-date on Mer Island, with ship rats being eradicated in 2013 (Leung, 2013). However, no formal measures have been put into place to prevent new rodent invasions as the Caring for Our Country project funding ceased in 2013. It could be argued that the training and experience received by some island residents in baiting procedures might allow some of these residents to bait future rodent incursions, but this action would need to be initiated and supported by the islanders themselves or a fresh source of funding secured.

The development of reactive strategies can also be seen in the quarantine plan for Barrow Island as discussed against the other actions above. In particular, this quarantine system involves the intensive surveillance and monitoring of key ports on the island for the presence of rodents and other pests (Jarrad et al., 2011a, Morris, 2011). This in turn allows for the early detection of any populations of rodents or other pests on the island and the reactive control of these populations before they become established.

Therefore, as outlined in the examples above, experience in the use of both prophylactic and reactive control strategies exists and can be drawn upon from these and other projects within Australia. Although the above examples cannot be called formal test studies of these strategies, the practical application of them can be considered as sufficient testing that they can be used to inform future eradication and control projects.

#### ***4.8 – Develop fast response capabilities to react to shipwrecks on priority islands***

In the quarantine plans and biosecurity measures discussed against the actions in this review, and throughout the literature on this subject, there is no mention of a contingency plan to deal specifically with shipwrecks. This very specific contingency may not be necessary in light of the proposals in actions 4.1, 4.2 and 4.7 above where there are monitoring and surveillance structures in place with the capacity to also deliver control tools in response to any rodent incursion on a priority island.. However, a shipwreck on a high risk island could present a high risk of reinvasion and it may therefore be beneficial to consider a contingency to deal with the occurrence of a shipwreck for future management plans. Contingency plans can likely be developed from the quarantine and rodent control experience developed in projects such as Barrow Island and Macquarie Island, amongst others.

#### ***4.9 – Actively involve island residents and ship owners in the management of incursion risks***

Island residents have been actively engaged in managing incursion risks on a number of islands. Some examples of this include Lord Howe Island and islands managed under Indigenous Protected Areas and participating in the Working on Country program. Barrow Island and Chevron Australia also involves members of its workforce in the monitoring of key areas for rodents and other pests.

On Lord Howe Island, members of the community have been directly engaged in managing the population of rodents in and around the main settlement on the island and some have undergone quarantine training to make them more aware of the risks that an incursion of a pest species to the island would pose (Lord Howe Island Board, 2014).

In some projects, the indigenous owners of the islands have been directly involved with the management of pests and protecting their islands from the threat of further incursions through monitoring and surveillance activities. Much of this work has been sponsored through the Working on Country program run by the Australian Government. An example of this is the Li Anthawirriyarra Sea Rangers and Yanyuwa Traditional Owners groups. The Sea Rangers are responsible for the management of the Sir Edward Pellew Islands and the riverine and coastal areas of the southwest Gulf of Carpentaria in the Northern Territory. This area of management includes eight large islands and more than 50 small islets and reefs and this ranger group is responsible for monitoring this area and managing the risks to their country including incursions from invasive species such as rodents (Department of the Environment, 2014b).

Another example from the Working on Country program of Indigenous island residents undertaking monitoring and surveillance for invasive species is the Bardi Jawi Rangers. This group is based at One Arm Point in the Dampier Peninsula in Western Australia. The Bardi Jawi Rangers were first established in 2006 with the aim of effectively managing the land and sea country of the Bardi and Jawi peoples in order to sustain traditional owners' livelihoods and connection to country and maintain its natural values. The ranger program



has taken part in many invasive species control and monitoring efforts including weed and feral animal control (Department of the Environment, 2014b). Most recently, the rangers, in cooperation with the WA Parks and Wildlife Department and the Invasive Animals CRC, undertook a survey of the rat population on Sunday/Iwany Island to determine its extent and the need for a control program (Island Arks Australia, 2014).

Many of the vessels that require pest control on inhabited islands would be owned by island residents, and therefore should be easier to maintain as rodent free, provided sufficient community buy-in for pest control could be encouraged. No stand out examples of such an education program have been found in the current literature, as most inhabited islands (Norfolk, Lord Howe etc) already have rodents present. As for other vessels visiting islands, in the cases where a permanent relationship between the vessel owner and the relevant authority on the island is established, then an agreement to manage the vessel under particular quarantine standards could be put in place. This is the case with the 'MV Island Trader' on Lord Howe Island (Lord Howe Island Board, 2009).

Barrow Island has multiple border controls to detect and deal with incursions of rodents on to the island (Chevron Australia, 2010). As far as the residents of the island and visiting vessels are concerned, the majority of visiting vessels and their passengers are respectively controlled by, or are employees of Chevron Energy, and would therefore be required to comply with the quarantine measures put in place by the company.

There has been some progress towards involving island residents and ship owners in the management of incursion risks from rodents in the examples given above, however, more can potentially be done to implement this action. For example, the involvement of traditional owners and indigenous ranger groups in the management of these risks, such as with the Li Anthawirriyarra Sea Rangers and the Bardi Jawi Rangers as mentioned above, could be seen as a good model for the engagement of other island residents. The engagement of ship or boat owners is another viable option at the community level. This measure would require significant community engagement as developing such agreements similar to the one between the Lord Howe Island Board and the 'MV Island Trader', require an island community to understand the problems caused invasions by rodents and a willingness to participate in the solutions.

## **Performance Indicators**

*Contingency quarantine and response plans for all islands are in place as part of feasibility studies or quarantine plans for high priority rodent-free islands.*

Against actions 4.1 to 4.3 and 4.7 to 4.9 above, there are examples of projects that have quarantine measures in place such as Barrow Island, Lord Howe Island and Macquarie Island. However, of these islands, only Barrow Island has a functioning incursion response plan in place, with the biosecurity plan for the recently pest free Macquarie Island still in the drafting stages. While not every priority island has a quarantine and response plan in place, the experience and expertise in rodent eradication and management is available to provide a basis for the development of new quarantine plans for high priority islands requiring protection in the future. This is another opportunity to collate and distribute this experience and

knowledge into a national best practice guideline (as referred to in this review against action 1.5) to inform future designs of eradication, quarantine, monitoring and control actions.

*Infestation rates on key Australian and foreign vessels are measured.*

As discussed in detail against actions 4.4 to 4.6 above, there are a number of examples of quarantine and biosecurity measures in place for specific islands that require the inspection of incoming cargo and personnel for potential biosecurity risks, such as rodent infestations. Infestation of cargo rather than specific vessels are determined both before they depart for their destination and upon arrival as is the case for the quarantine measures in place for Macquarie Island and Barrow Island (Australia Antarctic Division, 2012, Chevron Australia, 2010), or upon arrival at locations such as Lord Howe Island, (Landos, 2003). Whilst these quarantine measures do not focus on the rodent infestation of individual vessels, they do ensure that for the purpose of transporting either cargo or personnel to these key islands, that the vessel and its contents are free of rodents.

In contrast to this approach to biosecurity, the Lord Howe Island Board have negotiated an agreement with the ship the 'MV Island Trader' to undertake rodent control measures on board their vessel (Lord Howe Island Board, 2009). Because this ship makes regular (fortnightly) cargo deliveries to the island, maintaining a long term agreement with the company that runs the ship is necessary. This agreement to abide by certain sanitary requirements is the most efficient option available to the Lord Howe Island Board to maintain their quarantine.

When vessels are arriving from international ports, they are checked by the Department of Agriculture and Water Resources (Australian Department of Agriculture, 2014). The Departments' quarantine and inspection service requires under the *International Health Regulations (2005)*, that steps must be taken to keep vessels free of rodents and that all vessels greater than 25 metres have a valid Ship Sanitation Certificate. These measures should be sufficient to minimise the risk of rodent infestation on international vessels interacting with Australia's islands.

Rodent detection on vessels elsewhere in Australia are done on a priority basis. In many cases, only those vessels that will be visiting particular islands such as Macquarie Island or similar priority islands, have their cargo inspected for rodent infestation either before departure, or upon arrival (or both as is the case for Barrow and Macquarie Islands). While this approach to island biosecurity does not capture every vessel in Australian waters to determine its infestation status, it does channel usually limited resources to inspecting those vessels that pose a direct risk to these islands. This strategy has been effective for those islands employing them in the past five years. Barrow and Macquarie islands, in particular, have been successful in preventing new incursions of rodents by imposing measures on ships transporting people and materials to them (Department of the Environment, 2014a, Moore et al., 2010, Tasmanian Parks and Wildlife Service, 2013). Therefore, quarantine and biosecurity models such as those presented in the examples above are largely sufficient to protect islands from rodent incursions without the need to determine more broadly the infestation status of individual vessels.

## Conclusion

The objectives of this action group were to pursue measures that reduce the risk of the invasion or reinvasion of priority offshore islands by addressing two broad areas. The first of these was to put in place quarantine plans on these islands that included contingency plans to deal with new rodent incursions. The second was to determine the prevalence of rodents on vessels visiting priority islands, and using this information to limit rodent access to these vessels and control them where necessary.

Quarantine or biosecurity plans that has proven to be effective in preventing reinvasion are in place on Barrow Island and Macquarie Island already, with an improved biosecurity plan in draft for Macquarie Island (Australian Antarctic Division, 2012, Landos, 2003, Lord Howe Island Board, 2014, Moore et al., 2010). Additionally, there have been positive steps in island quarantine taken on Lord Howe Island, even though this plan cannot be said to be an example in preventing reinvasion due to the continuing presence of ship rats on the island. These plans should be considered as excellent examples to inform future quarantine strategies for islands considered a priority.

Contingency plans to deal with potential reinvasions have received less attention in the past five years. The ability to implement such plans has been gained through experience in eradication and control programs undertaken on Barrow Island, Macquarie Island, Lord Howe Island and Mer Island. In particular, the targeted surveillance and monitoring program on Barrow Island (Jarrad et al., 2011a, Moore et al., 2010) and the surveillance and hunting programs implemented as a part of the Macquarie Island Eradication Project (Moore et al., 2010, Tasmanian Parks and Wildlife Service, 2013, Tasmanian Parks and Wildlife Service, 2010b) should provide good templates upon which contingency plans and incursion response programs to complement the quarantine systems can be based upon.

Surveys of rodent infestations on vessels have been used on some islands. For example, on Lord Howe Island, the vessel the 'MV Island Trader' has an agreement with the islands governing board to undertake rodent control on this vessel. Additionally, the Department of Agriculture and Water Resources carries out inspections of international vessels entering Australian ports.

More of the focus in the past five years has been on quarantine measures to prevent incursions by targeting cargo inspections both before departure and on arrival, as well as people arriving on islands, rather than surveying ships for rodents generally. For example, this process is in place as part of the Barrow Island quarantine program (Chevron Australia, 2010, Jarrad et al., 2011a). The more general surveying of vessels that land on priority islands may be useful to direct quarantine efforts more effectively in future. However, investment in this kind of activity is unlikely to be the focus of future actions to prevent invasion or reinvasion of priority islands, as the proven effectiveness of pre and at border quarantine coupled with targeted monitoring and control is likely to be more appealing to land managers.

In conclusion, the experience gained from the quarantine and biosecurity programs listed above in surveillance, monitoring, contingency planning for responses to incursions, and the ability to implement targeted control is significant. Looking forward, this should mean that future projects looking to put in place similar quarantine plans will have excellent examples to follow and should be able to adapt these examples to suit their situations.



## **ACTION GROUP FIVE OF THE 2009 TAP**

### **3.3.5 Actions to achieve outreach and public education**

The 2009 TAP stated;

These actions aim to ensure that the plan's actions and outcomes are understood and actively supported by island residents, traditional owners and other interested parties. This support is important during feasibility planning for eradication to address potential concerns about the risks involved with control methods such as aerial poisoning, which by its nature is conducted by agencies or contractors. However, it is even more important to involve island residents and other parties in the ongoing management of reinvasion risks, quarantine and sustained control, which by its nature requires the active participation of the wider public.

5 – Actions to achieve outreach and public education	Priority and timeframe
5.1 Promote stakeholder input and involvement as the Threat Abatement Plan is implemented	High priority, short term
5.2 Actively consult with traditional owners of islands	High priority, short term and ongoing
5.3 Promote the conservation benefits of successful eradications to the wider Australian public	Medium priority, medium term
5.4 Identify boat owners who visit key islands, and develop an education package to ensure their vessels are free of rodents	High priority, long term

### **Current state of actions**

Stakeholder interest in this plan is high for some conservation groups and from the residents of some islands. However, there has been no formal consultation with traditional owner organisations or boat owners about the Threat Abatement Plan. The lack of input from traditional owners will have to be remedied particularly at the level of detailed consultation with the actual owners of any islands intended for actions.

### **Performance indicators**

- The Plan is widely accepted as an action resource by stakeholders
- The Plan will be used as the basis for ongoing consultation with appropriate representatives of traditional owner groups, and direct consultations with particular traditional owners of islands mooted for actions
- A resource kit 'keeping your boat free of rodents' for boat owners is developed and made available

### **Assessment of Progress**

#### ***5.1 – Promote stakeholder input and involvement as the Threat Abatement Plan is implemented***

The implementation of Threat Abatement Plans (TAPs) relies on a partnership between the Australian Government and relevant stakeholders to progress the priority actions identified in the plan. This is particularly the case with TAPs where the Australian Government has limited jurisdiction to implement actions on the ground (such as islands under state and territory

government jurisdiction). Some funding for implementation of TAP actions has been available through the Caring for Our Country program. Funding from this programme has led to some positive outcomes (such as the project on Mer Island).

Despite limitations on funding, most of the projects aligning with the actions in the 2009 (such as Macquarie Island and Montague Island) TAP have been implemented by state and territory governments, research organisations and non-government organisations. Therefore partnerships and engagement with state and territory governments will continue to be very important for future TAP implementation. Examples of the projects by state and territory governments and other land managers such as the Lord Howe Island board aligning with the actions of the 2009 TAP include rodent eradications undertaken on Montague, Macquarie Islands and future planning for the rodent eradication on Lord Howe Island (as discussed against action group 2 in the text above). Additionally, there have been a number of projects funded through the Caring for Our Country program that have aligned or partially aligned to the actions in the TAP such as the Mer Island eradication project (Department of the Environment 2014b, Caring for Our Country, 2009).

The Mer Island eradication project was quite successful in engaging stakeholders and actively involved these stakeholders in projects. This eradication project was undertaken in the Torres Strait by Dr. Luke Leung and his team from the University of Queensland (Leung, 2013). The project was funded by the Caring for Our Country program between 2009 and 2012 with the aim of eradicating invasive rodent species such as ship rats and house mice and improving community engagement on land management issues (Landcare Australia, 2011). This project involved significant consultation with the indigenous land owners including the Torres Strait Regional Council and sought their knowledge on the invasive rodent population and the native rodent species present on the island (the Grassland Melomys). Some members of the regional council, as well as two members of the Mer Island Rangers, received training in control techniques and eradication program design from the project team.

Another example of encouraging the involvement of stakeholders in the implementation of the TAP actions is the funding of a number of island eradication projects in WA by the Caring for Our Country program. These projects involved the participation of the Western Australian Department of Environment and Conservation and were funded between 2009 and 2012. The projects aimed to eradicate invasive rodents from Boullanger, Whitlock, Three Bays, Faure, Thevenard, Figure of Eight, Sunday, Long, Boxer, Woody, Mistaken and the Direction (Cocos Keeling) Islands. This project aligned to many of the actions in the 2009 TAP, including protecting biodiversity and natural values from the effects of invasive rodents and improving community skills knowledge and engagement regarding the control and monitoring of these animals (Caring for Our Country, 2009).

As outlined above, there has been some effort to encourage the input and involvement of stakeholders in projects that align to the implementation of the TAP actions. However, much of the implementation of these actions has been achieved through projects undertaken by state governments, non-government organizations and other groups such as researchers. While the model of providing funding to provide incentives to other organizations has been a reasonably effective one in encouraging these groups to implement projects aligned to the 2009 TAP, more could be done to align the priorities of the TAP to those of the state governments and other organizations. This would encourage more active participation of these groups in delivering the objectives of either the current TAP or any future plan without such a need for funding incentives. It is likely that in the future, the need to work more closely with these

agencies and groups in order to achieve implementation, will become more necessary in a tightening financial environment.

## ***5.2 – Actively consult with traditional owners of islands***

There are a number of examples of eradication or control projects where indigenous owners of islands have been actively engaged and consulted on the process undertaken. Indeed with many of these projects, traditional owners have been directly involved in the implementation process.

As discussed in action group 3 above, some examples of island residents being consulted and involved in the control of invasive species are evident under the Working on Country program. These include the the Li-Anthawirriyarra Sea Rangers and Yanyuwa Traditional Owners groups of the southwest Gulf of Carpentaria in the Northern Territory and the Bardi Jawi Rangers based at One Arm Point in the Dampier Peninsula in Western Australia (Department of the Environment, 2014b). The involvement of these traditional owner groups and the consultation this has involved has been covered in detail against action group 3 above.

The Working on Country initiative has proven highly successful to date due to the uptake of the program by a number of traditional owners groups, and the successes they have achieved in invasive species and land management as outlined elsewhere in this review (Department of the Environment, 2014b). This includes consultation of traditional owners by state and territory governments in order to achieve invasive species management projects on their lands.

Another instance of traditional owners being directly engaged in order to achieve the control of invasive species is the eradication programme undertaken on Mer Island in the Torres Strait. This project took place between December 2009 to 31 December 2012 under the supervision of the University of Queensland's Dr. Luke Leung, and with funding from the Caring for our Country program. The purpose of the project was to attempt the eradication of ship rats and house mice from the entirety of Mer Island. During the course of the project, the staff were assisted by both members of the Torres Strait Island Regional Council and the Mer Island Rangers, all of whom were involved in the design and implementation of the baiting program (Leung, 2013). This consultation with the traditional owners contributed directly to the success of the eradication program by helping to identify the areas of greatest invasive rodent concentration. This also helped the project team avoid unintended impacts on the native grassland melomys by allowing the baiting to be targeted to occupied areas based on the advice provided by the locals.

## ***5.3 – Promote the conservation benefits of successful eradications to the wider Australian public***

Montague, Macquarie and Barrow Islands are good examples of successful public relations exercises for eradication projects. However, many island eradications often receive minimal press attention and are not mentioned as conservation success stories except perhaps in ecology-specific scientific journals.

The promotion of the benefits achieved through the eradication of rodents and other invasive species from islands has been approached in a fairly haphazard manner and has had variable success with reaching the Australian public. Some key projects, such as the eradication

success recently achieved on Macquarie Island, have not only been promoted widely and reasonably consistently, they have been able to capture at least some of the attention of the greater public through these efforts. For example, the recently released review of the Macquarie Island eradication project by Tasmania Parks and Wildlife service (Tasmanian Parks and Wildlife Service, 2014) demonstrates not only the benefits that this eradication project has had on the ecology and native species on Macquarie Island, but also demonstrates the kind of monitoring data and imagery that is needed to demonstrate these benefits to the general public. Despite these positives from the Macquarie Island project, indications given by the review document (Tasmanian Parks and Wildlife Service, 2014) point to an overall reduction in the monitoring of the recovery of the native flora and fauna on the island. This reduction in monitoring may reduce the evidence-base needed to effectively demonstrate the benefits of eradication projects to both the public and potential investors in future projects. As is quoted in the Macquarie Island project review document;

*“Government budgetary constraints sometimes threaten or reduce the availability and/or security of funding to support monitoring and research activities and staff positions for studying the recovery of affected species, communities and landforms on Macquarie Island.” and “Allocated budget resources to support a planned program of monitoring and research to measure, document and communicate the impact of this major project – including ongoing recovery of the island’s plant and animal communities and ecological processes beyond the life of the project – would be highly desirable.”*

A potential strategy to combat this lack of publicity and public outreach (based upon the monitoring programs as proposed above) is to include in project budgets funds for: immediate publicity at the initiation of the project in order to gain community support for its implementation; on completion of the eradication project, a publicity campaign to celebrate and promote the completion of the works and their potential benefits; and finally, the initiation of a longer term publicity campaign to track the recovery of the island in question and to promote the positive outcomes of eradication and island conservation work.

In contrast to the Macquarie Island project, the promotion of eradication projects on Montague Island in NSW and Mer Island in the Torres Strait have been less penetrating, despite the relative success of both these projects in removing rodents. Montague Island had both house mice and European rabbits eradicated in 2011 (Cory et al., 2011a, Priddel et al., 2011) with the completed project determined to have some success in restoring the seabird nesting habitat on the island (see action group 2 for further details of this project). However, in contrast to Macquarie Island, the public’s exposure to the positive outcomes of this project has had less impact, despite press releases being posted on the NSW Parks and Wildlife website, published papers in scientific journals (Cory et al., 2011a, Priddel et al., 2011), and three newspaper articles published in the Narooma News, Canberra Times and the Sydney Morning Herald. Unfortunately, a lack of monitoring of the ecology of the island after the eradication of rodents has meant that the benefits arising from this action are somewhat difficult to demonstrate.

Considering the above examples, a continuing strategy to promote the advantages of island eradications of invasive species and island conservation in general, should be further investigated. Many of these successful eradication projects in Australia (Gregory et al., 2014) offer “easy wins” in terms of positive outcomes for the conservation effort they require and the demonstration and promotion of these outcomes should be used to advocate for similar future projects.



#### **5.4 – Identify boat owners who visit key islands, and develop an education package to ensure their vessels are free of rodents**

The potential for recreational and commercial boat traffic to spread invasive pests and diseases has been identified as a significant problem for islands by the organisations that manage them. For example, the Queensland Department of State Development, Infrastructure and Planning and the Queensland Parks and Wildlife Service, in conjunction with the Great Barrier Reef Marine Park Authority produced a document under the Great Barrier Reef Coastal Zone Strategic Assessment 2013 (Queensland Parks and Wildlife Service, 2013) using the management of islands on the Great Barrier Reef as a case study on effective environmental management (named the *Island management demonstration case*). This document identifies the incursion of feral animals, weeds and diseases as one of the most prevalent threats to the health of these island ecosystems, and identifies both commercial (usually tourism based) and recreational boat traffic as potential transport vectors for these invasive species. It is acknowledged in this document that although the islands in the Great Barrier Reef have been relatively well managed in terms of having populations of feral animals eradicated, more needs to be done in the quarantine and surveillance of these islands in order to prevent new incursions.

Apart from the document mentioned above, little to no progress has been made on this action in the past five years. Although there are examples where specific vessel owners visiting key islands have been engaged to ensure their vessels are rodent free (such as the case with the MV Island Trader visiting Lord Howe Island – See Action 4.9) (Lord Howe Island Board, 2009), there is no indication that a specific education package has been developed for broader outreach to boat owners by state agencies or other organisations managing island biosecurity.

As discussed elsewhere in this review, experience in island biosecurity has been developed through projects such as Macquarie Island and Barrow Island. The quarantine and surveillance measures in place for both of these islands could be used as the basis of an education package to inform recreational and commercial boat operators of the risks of transporting invasive species to key islands.

### **Performance Indicators**

*The Plan is widely accepted as an action resource by stakeholders*

- The TAP has been referenced by state and territory agencies seeking funding from Australian Government sources such as Caring for our Country and the Biodiversity Fund. For example, funding was provided for a number of island eradication projects in WA on Boullanger, Whitlock, Three Bays, Faure, Thevenard, Figure of Eight, Sunday, Long, Boxer, Woody, Mistaken and the Direction (Cocos Keeling) Islands (Caring for Our Country, 2009). All of these projects aligned themselves to many of the actions in the 2009 TAP, including protecting biodiversity and natural values of sites from the effects of invasive rodents and improving community skills knowledge and engagement regarding the control and monitoring of invasive animals. As discussed previously in this document, some of the projects referenced against the actions listed above have likely been intentionally aligned to some of the actions of the 2009 TAP for either funding support from the Australian Government or because the priorities of both national and state governments aligned at the inception of the projects (e.g. the Macquarie Island eradication

project). However, there is no reference in these projects to suggest that they were initiated specifically to align to the actions in the 2009 TAP or that the TAP had been used as a resource to dictate the project's conservation priorities.

*The Plan will be used as the basis for ongoing consultation with appropriate representatives of traditional owner groups, and direct consultations with particular traditional owners of islands mooted for actions*

- It is not clear how the TAP has been used during indigenous consultation by various agencies engaged in island conservation work. It could be argued that government programs engaging with Indigenous communities, such as the ongoing Working on Country program, may make reference to the 2009 TAP document when specifically addressing island conservation work involving invasive rodents in order to garner funding support. It is not sufficiently demonstrated however, that the 2009 TAP has been “*used as the basis for ongoing consultation with appropriate representatives of traditional owner groups*”. In some instances, such as the eradication work in WA mentioned against the performance indicator above (Caring for Our Country, 2009), the TAP document and its stated actions have been used to gain funding for successful eradication and management projects involving the indigenous owners and residents of these islands. This can be seen as a positive for the promotion of some of the objectives of the TAP but does not seem to indicate a more ubiquitous uptake of the TAP and its actions as a basis for consultation.

*A resource kit 'keeping your boat free of rodents' for boat owners is developed and made available*

- No such resource kit has been developed by the Australian Government, nor by any state or territory government agency, for this purpose. However, the movement of invasive species by both commercial and recreational boat traffic has been acknowledged by the Queensland Government as a key issue threatening the biosecurity of islands in the Great Barrier Reef (Queensland Parks and Wildlife service, 2013). In future, education and outreach programs such as those proposed in action 5.4 and in this performance indicator, can be developed based upon quarantine and biosecurity experience gained on projects such as Barrow Island (Chevron Australia, 2010, Jarrad et al., 2011a) and Macquarie Island (Tasmanian Parks and Wildlife Service, 2010c, Tasmanian Parks and Wildlife Service, 2013, Tasmanian Parks and Wildlife Service, 2014) and arrangements made for the shipping transport to Lord Howe Island (Landos, 2003, Lord Howe Island Board, 2009)

## **Conclusion**

The objective of this action group was stated as “to ensure the plan's actions and outcomes are understood and actively supported by island residents, traditional owners and other interested parties” and more broadly to achieve public outreach and education on the benefits of island conservation actions. An examination of whether these objectives have been met over the past five years is laid out below.

The promotion of stakeholder input into the implementation of the TAP has been achieved through partnerships with state and territory governments as well as some private organisations.

Action 5.2 sought to 'Actively consult with traditional owners of islands', and this action has been partially fulfilled by the activities of the Working on Country program. Many of the indigenous ranger programs have contributed to this action through their activities aligning with some actions in the 2009 TAP document (as discussed above, and against actions 4.9 and 3.3 above). However, these activities are not usually due to using the TAP as a direct resource to determine the work of these ranger groups.

The promotion of the conservation benefits of successful eradications to the public has not been pursued consistently since the 2009 TAP was released. Although there have been some genuine conservation wins from island eradication projects in this period, such as Montague Island, Mer Island, the WA Islands work mentioned in the paragraphs above, and Macquarie Island, it has only really been the Macquarie Island eradication and Montague Island eradication projects that have had partial success in promoting themselves to the public (Tasmanian Parks and Wildlife Service, 2014).

The action to develop an education package for boat owners on keeping their vessels free of rodents has not been achieved to date. While the transport of invasive species by boats has been identified as a major problem on the Great Barrier Reef (Queensland Parks and Wildlife service, 2013), and some examples of effective biosecurity for vessels can be seen on Barrow Island, Macquarie Island and the quarantine arrangements in place for Lord Howe Island (Chevron Australia, 2010, Jarrad et al., 2011a, Landos, 2003, Lord Howe Island Board, 2009, Tasmanian Parks and Wildlife Service, 2014), there has been no education package of this kind developed either at the Australian Government or state and territory level. However, a package of this kind could potentially be developed based upon the experience gained in other eradication projects and quarantine plans.

In conclusion, the overall objectives of this action group to achieve the recognition and uptake of the TAP and its actions, has had some success in specific areas. These include indigenous engagement through the Working on Country program and the successful promotion of the Macquarie Island eradication project by both Tasmanian Parks and Wildlife Service and the Australian Government. However, despite these successes, the public exposure of both the TAP and its actions and the success of projects aligning to these actions has been limited. More could be done in future to both promote the TAP document and its objectives, and to promote successful projects that implement these objectives to the public. A more consistent approach to supporting monitoring and research activities that document the positive impact rodent control projects have on islands, and a more consistent approach to educating the public on these outcomes, would assist in winning more support for these projects and the actions of the TAP in future.

## **ACTION GROUP SIX OF THE 2009 TAP**

### **3.4 Research and information needs**

The 2009 TAP stated;

Research on the management of exotic rodents on islands is being conducted in many countries — Australian researchers and managers need to be able to access these results. However, within Australia five key gaps are identified:

- The possibility that the presence of ship rats reduces the chance to eradicate mice needs to be tested and the causes identified. This is not just an Australian problem, so researchers need to liaise with overseas colleagues to develop dual-species or one-at-a-time strategies for managing mice in the presence of ship rats.
- Best-practice use of toxic baits (and other control methods) and adequate monitoring protocols for sustained control options need to be formulated and tested.
- The humaneness of control methods remains an issue and ongoing research is required to improve the animal welfare costs of rodent control.
- Information on the risks of invasion by exotic rodents on islands of different types needs to be gathered to develop a risk profile for key islands. Best-practice surveillance and intervention (by prophylactic measures such as permanent bait station around wharfs, or reactive measures such as surveillance and prompt response to a detection) need to be developed, applied where appropriate, and tested over the long term.
- The consequence of exotic (or native) predators switching to native prey from exotic rodents as primary prey may be an issue on islands. The precautionary approach is to remove exotic predators at the same time as the exotic rodents, but if this is not possible, predicting and testing the consequences is desirable before rodents are removed.

6 – Actions for research and information needs	Priority and timeframe
6.1 Determine why mice appear to be more difficult to eradicate in the presence of rats	Very high priority, short term
6.2 Develop best-practice guidelines for sustained control of rodents on islands	High priority, short term
6.3 Improve the humaneness of eradication tools	High priority, long term
6.4 Develop and test risk-based methods to detect and manage incursions by rodents	High priority, short term
6.5 Predict and test the consequences of prey switching	Medium priority, medium term

### **Current state of actions**

All of these research actions are being addressed either in Australia or elsewhere. The issue of sympatric mice and ship rats is a particular problem on Australian islands.

### **Performance indicators**

- Australian research on the mouse-rat issue is developed and integrated with research being conducted in New Zealand and the USA.

## **Assessment of Progress**

### **6.1 – Determine why mice appear to be more difficult to eradicate in the presence of rats**

The literature on this subject seems to indicate that while certain trends have been observed in inter-species interactions between mice and rats (or rats and other rodent species) during eradication and control programs, the specific question of why mice appear to be more difficult to eradicate when rats are present in the same environment has not been specifically tested. Still, some trends have been noticed in relation to the behaviour of mice in the presence of rats during the course of eradication and control projects involving both these rodents. This knowledge on observed trends in behaviour has been applied to the eradication of mice in such situations, for example, the successful eradication of mice, ship rats and European rabbits on Macquarie Island (Tasmanian Parks and Wildlife Service, 2014).

The most prominent theory on the difficulty of mice eradications in the presence of rats, is that these two rodent species compete for very similar resources. However, due to the physical domination of mice by larger rodents such as ship rats, Norway rats, Pacific rats and even European rabbits, the mice will generally have fewer resources available to them in the presence of these species. This seems to lead to house mice altering their feeding behaviour, home range size and diet in order to better cope with this competition (Harper and Cabrera, 2010, Howald et al., 2007). Therefore, during eradication projects aimed at both mice and rats (and other rodent species) that use toxic baits to achieve eradication, the most common tactic employed is to ensure that the amount of bait available to all rodent species is sufficient to allow all individuals in the population to accumulate a lethal dose of the toxin despite the additional competition some of these rodents experience. This is usually achieved by sufficiently high bait broadcast rates as well as the employing multiple, staggered bait broadcasts to ensure a consistent and prolonged bait exposure for the rodent populations. This tactic has been refined and employed to great success on Islands including Montague Island in NSW, and Macquarie Island in the Subantarctic (Cory et al., 2011b, Springer, 2011, Tasmanian Parks and Wildlife Service, 2010a). These measures have been formally noted as a tactic to achieve successful eradication of rodents on islands in the recently published best practice guidelines on the eradication of rats using aerial baiting produced by the New Zealand Department of Conservation (Broome et al., 2014).

While further research into the interactions between mice and rat species (as well as interactions with other species) is needed, the method discussed above has largely improved the success rates of mice eradications in recent years (Cory et al., 2011a, Tasmanian Parks and Wildlife Service, 2014). However, in situations where a high baiting density poses an unacceptable risk to native species, a better understanding of the interactions between mice and ship rats may provide alternative tactics to achieve eradication success.

### **6.2 – Develop best-practice guidelines for sustained control of rodents on islands**

A set of national best practice guidelines that encompasses all aspects of either eradication activities, or management and sustained control activities has not yet been produced for Australian conditions. However, there have been a number of documents produced elsewhere, such as the Pacific Islands Initiative *Resource kit for rodent and cat eradication* (Secretariat of the Pacific Regional Environment Programme, 2009) that represent a practical model to assist land managers in the control or eradication of invasive species. This resource kit sets out a number of project design principles that have been applied and proven to be effective in the

past. This document is a good example of how a future best practice management and eradication document could be set out for Australian application.

Three recently released articles on this subject (in addition to the Pacific Islands Initiative document mentioned above) have partially covered the successful eradication techniques that have been developed and achieved in past eradication projects. The first article, produced in collaboration between the Invasive Animals CRC and the University of Adelaide (Gregory et al., 2014) deals with past eradication projects in Australia and uses the data from these projects to inform future best practice in conducting eradication projects. This document is a useful examination of a large dataset of island eradication attempts and has used the evidence supplied by this data to set out in its 'Eradication best practice' section a number of principles for best practice eradication techniques. These include procedures and concepts such as 'feasibility planning' and 'pre and post eradication monitoring', with supporting literature and examples for each of these. While this paper provides an excellent starting point for land managers and conservationists to pursue an eradication or control project, it still requires additional research into the example projects cited to determine the techniques used in each and identify which of these might be suitable to use as a model.

The second article, is a 2014 paper titled *Best practice guidelines for rat eradication on tropical islands* (Keitt et al.). This paper utilises past examples of eradication attempts on tropical islands in order to inform and present a number of principles of rodent eradication in the tropics. It also examines the lower success rates of eradication projects in tropical areas. While this paper does not address sustained control techniques (it is mainly focussed upon eradication techniques), the information and planning techniques provided would still be useful in the context of sustained rodent control.

Thirdly, the New Zealand Department of Conservation has recently published a document detailing the best practice procedures for rat eradication using aerial baiting techniques (Broome et al., 2014). This document deals almost exclusively with eradication techniques for temperate and high-latitude islands through the use of aerially broadcast second generation anticoagulant baits. This is the technique used to great effect on Macquarie Island and Montague Island (Tasmanian Parks and Wildlife Service, 2014, Cory et al., 2011a). The New Zealand Department of Conservation is one of the best practitioners of this technique and of island eradications in general, and as such, this information should be noted and incorporated in any best practice documents in the future.

The above examples of already produced best practice documents, along with models and lessons learnt on islands such as Macquarie and Barrow Islands, amongst many others, represent a significant body of knowledge. This coupled with other international experience from eradication and pest management projects should make it possible to draft best practice guidelines to achieve sustained rodent control on islands.

### **6.3 – Improve the humaneness of eradication tools**

In most of the literature cited in this review, it is acknowledged that the most effective tool for the eradication of rodents on offshore islands at present, is the broad-scale distribution of second generation anticoagulant baits (Broome et al., 2014, Cory et al., 2011b, Howald et al., 2007, Tasmanian Parks and Wildlife Service, 2010b). However, many second generation anticoagulants (such as brodifacoum and bromadiolone) are considered to be inhumane to the animals they target. This is due to the prolonged and presumably painful, internal

haemorrhaging leading to the animal's death. The delay before the onset of symptoms is considered to be useful in preventing rodents that consume a sub-lethal dose associating the effects of the toxin with the consumed bait, and thereby developing an aversion to consuming the baits in future. However, other active toxins may provide viable alternatives and be considered to be more humane (McLeod and Saunders, 2013).

Despite the concerns over the humaneness of the second generation anticoagulants for eradications and their high rate of persistence in the animals that have died from consuming these baits (thus causing secondary poisoning of animals that may eat the carcasses), they remain some of the most proven, effective, and cost effective baits for broad scale rodent eradication (Priddel et al., 2011, Cory et al., 2011b, Tasmanian Parks and Wildlife Service, 2014, Gregory et al., 2014).

While some alternatives exist such as cyanide, zinc phosphide, cholecalciferol, coumatetralyl and diphacinone (Eason et al., 2010), most of these toxins have not been registered for broad scale use in Australia. Further, their efficacy in such situations has not been proven to the extent that brodifacoum has (McLeod and Saunders, 2013, Eason et al., 2010). However, some of these alternative baits address both the humaneness issue and the accumulation/ potential secondary impact issue to some degree (Eason et al., 2010). Further testing is still needed to establish the feasibility of these alternative toxins for island wide eradications.

For further information see table 3 below.

**Table 3;** Comparison of 5 alternative baits to Brodifacoum (information extracted from (Eason et al., 2010, McLeod and Saunders, 2013)

Compound	Mode of action	Speed of action/ humaneness	Persistence in tissue/ secondary poisoning potential
Cyanide	Acute anoxia of the central nervous system and disrupts  Energy metabolism and cellular respiration.	Time to death dependent on dosage: from 1 minute to 3 hours.  Rated highly humane compared to brodifacoum	Rapid decay (likely <12 hours)/ Low
Zinc Phosphide	Reacts with stomach acids to produce phosphine gas causing central nervous system depression, irritation of the lungs, and damage to the liver, kidney and heart.	Time to death dependent on dosage. 20 minutes to multiple days.  Moderate humaneness compared to brodifacoum	Rapid decay (likely <12 hours)/ Low
Cholecalciferol	Disrupts calcium metabolism and produces hypercalcemia causing kidney, heart or respiratory failure, or haemorrhaging from the calcification of blood vessels and internal organs.	2-6 days, although periods of up to 11 days have been recorded  Moderate humaneness compared to brodifacoum	10- 68 days persistence in blood and tissue/ Moderate
Diphacinone	Inhibits the vitamin K reductase, depleting	In rats ( <i>Rattus</i> sp.) 3-14 days, mice ( <i>Mus</i> sp.) 3-21	3 days/Low

	the level of blood coagulation factors disrupting the blood's ability to clot.	days.  Moderate humaneness compared to brodifacoum	
Brodifacoum	Inhibits the vitamin K reductase, depleting the level of blood coagulation factors disrupting the blood's ability to clot.	In rats ( <i>Rattus</i> sp.) 3-14 days, mice ( <i>Mus</i> sp.) 3-18 days  Poor humaneness	130 - 300 days/ High

#### **6.4 – Develop and test risk-based methods to detect and manage incursions by rodents**

There have been a number of studies dedicated to already functioning quarantine and surveillance methods for rodents on islands. For example, Barrow Island and its quarantine model is a good example of effective use of available resources to achieve positive outcomes through surveillance rather than through repeated chemical control (Morris, 2011). However, a standard model for the detection and management of potential rodent incursions onto islands has not been developed to-date. The question of how best to allocate resources to detect and manage any new rodent incursions on islands therefore tends to be addressed specifically in each project to suit the conditions in the field (Tasmanian Parks and Wildlife Service, 2014, Tasmanian Parks and Wildlife Service, 2010b).

Many lessons can be learnt in this area from successful eradication and management projects for rodents. Often the post eradication monitoring of an island is neglected due to a lack of funding for these procedures beyond the eradication attempt. However, there are a number of successful projects that have instituted monitoring programs to prevent reinvasions or the re-emergence of rodent populations. These programs and the methods used therein can inform future monitoring and surveillance programs. Of particular note is the Barrow Island quarantine program which has successfully excluded rodents from the island for a number of years (Greenlade et al., 2013b) and the successful post eradication monitoring program put in place for the Macquarie Island project (Tasmanian Parks and Wildlife Service, 2010c, Tasmanian Parks and Wildlife Service, 2014).

If the surveillance methods developed through the implementation of these successful projects can be transferred to future projects (perhaps with greater emphasis on monitoring and assessment of the impacts of these methods), then it should be possible to refine them and apply them to a broader range of eradication and management projects.

#### **6.5 – Predict and test the consequences of prey switching**

While the consequences of prey switching and other trophic cascade effects have not been specifically tested for, they have been observed in certain projects in the post eradication phase. For example, the Macquarie Island eradication project's post eradication monitoring phase noted an increased level of predation of Antarctic prions and white-headed petrels by skuas and other native predatory birds on the island after the removal of rabbits as a food resource. Although consequential effects of this kind were expected, the positive influence of the removal of invasive rodent species from the island, and the resulting decrease in rat predation and habitat destruction by rabbits that this delivered, far outweighed the negative effects (Tasmanian Parks and Wildlife Service, 2014).



An international example of an unintended consequence of a change in predator from rats was seen on Anacapa Island off the California coast in the USA. This project involved the removal of black rats from the island to assist in the recovery of the ground nesting seabird, the Scripps Murrelet. The project was initiated in 2001 and succeeded in eradicating rats from the island in 2002. Monitoring of the murrelet population was continued until 2011 (Whitworth et al., 2013). The removal of rats led to a measured 50% increase in hatching success for the murrelets over the study period, but also resulted in unintended consequences. Native deer mice (*Peromyscus maniculatus anacapae*), which were reintroduced to the island after the rats were removed, replaced the rats as the main contributor to egg predation on the murrelets nests. While this predator switch did not ultimately affect the recovery of the Murrelet population, it does demonstrate that unintended outcomes can emerge from the removal of an invasive species.

Despite the lack of dedicated research relating to trophic cascade effects and prey switching, the lessons learnt from the observed unintended impacts of rodent eradication projects such as on Macquarie Island and other projects, has led to a far more holistic approach being adopted for the implementation of eradication programs. This means that multiple invasive species are often removed concurrently. In addition to this practice, potential unintended consequences through the removal of invasive species are often accounted for in the planning phases of new projects and the benefits of the removal of invasive species are weighted against the risk of any unintended outcomes (Springer, 2011, Veitch et al., 2011).

### **Performance Indicators**

*Australian research on the mouse-rat issue is developed and integrated with research being conducted in New Zealand and the USA.*

No significant specific research has been conducted on this issue in Australia. Certain interactions between mice and other rodent species have been observed in projects where the eradication of multiple species of rodents (Macquarie, Anacapa, Surprise Islands etc. (Caut et al., 2009, Tasmanian Parks and Wildlife Service, 2014, Whitworth et al., 2013)). These observations have shown that the mouse-rat issue can be primarily explained by competition between mice and rats for resources which causes mice to have insufficient access to toxic baits to receive a lethal dose during eradication campaigns. It has also been postulated that the presence of rats can cause changes to the feeding behaviour of mice and a reduction in their home ranges (Harper and Cabrera, 2010). This inhibition of mice has been countered by employing specific baiting tactics and these tactics have proven reasonably successful in eradicating mice in situations where they are interacting with other rodent species (including rats) such as the Montague Island eradication project and the Macquarie Island eradication project (Cory et al., 2011a, Tasmanian Parks and Wildlife Service, 2014). However, further development of different approaches to address this issue in a range of situations is still needed to account for situations where the saturation baiting of an island is not a viable alternative.

### **Conclusion**

The objectives of this action group were designed to meet the information and research needs of land managers and conservationists undertaking the management of rodents on offshore islands. This was to be achieved by filling the gaps in our knowledge of the ecological interactions of invasive rodents on islands. Additionally, the goal was to improve the control or

eradication of rodents by improving upon existing techniques and tools through research and testing. While some progress has been made against a subset of the actions listed above, the majority of this progress has been through the observation and recording of techniques and tools used on successful eradication and monitoring projects such as Barrow Island and Macquarie Island (Greenslade et al., 2013b, Tasmanian Parks and Wildlife Service, 2014). Additional insights have been gained by monitoring the recovery or changes of the islands ecology to the removal of invasive rodent species.

In relation to action 6.1, there has been no direct testing of the interactions between rats (as well as other rodents such as rabbits) and mice that clarifies why mice are more difficult to eradicate when interacting with other species. However, these interactions have been observed and strategies to cope with the interference of other species developed, including the modification of baiting techniques to account for competition between mice and rats (Broome et al., 2014, Tasmanian Parks and Wildlife Service, 2010b). These measures appear effective. More research would be beneficial in this area to offer a greater range of tactics to pursue when these pests are encountered in situations where the current techniques cannot be used due to the risk of secondary impacts to native species or there are other impediments.

Concerning action 6.2, a set of best practice guidelines for the control or eradication of rodents on islands has not been developed in Australia, at least not in the form of a set of practical guidelines that can be used to advise new eradication or control projects. However, a number of scientific papers examining the track record of various eradication projects and listing successful techniques and project planning concepts have been produced (Broome et al., 2014, Gregory et al., 2014, Keitt et al.). A great deal of experience in both the eradication and sustained control and the techniques and strategies to implement these exist in Australia and New Zealand from projects where rodents have been successfully eradicated or controlled. These include Barrow Island, Montague Island and Macquarie Island in Australia (Priddel et al., 2011, Tasmanian Parks and Wildlife Service, 2014). As well as the experience gained from these projects, a number of exemplar documents have already been produced by the Pacific Islands Initiative with their *Resource kit for rodent and cat eradication* (Pacific Islands Initiative, 2011), the New Zealand Department Of Conservation's *Rat eradication using aerial baiting Current agreed best practice used in New Zealand* (Broome et al., 2014). These two examples can be used as a reference for the development of a similar document in Australia. The development of this best practice guideline document for eradications and control projects, as suggested throughout this review and in action 1.3 of the 2009 TAP, could be undertaken using this body of information.

Action 6.3 deals with the development of control tools for rodents that are more humane than the currently favoured second generation anticoagulants such as brodifacoum. However, while some of the newly developed toxins, such as cyanide and zinc phosphide paste are considered far more humane than brodifacoum (Eason et al., 2010), these agents don't have the proven track record of brodifacoum and are not as cost effective for large scale projects. Therefore, it seems likely that brodifacoum will remain the toxin of choice for eradications until more efficacy trials can be undertaken for alternative control tools.

Action 6.4 has not had specific trials or studies pursued to develop 'risk based methods' for the detection and control of rodents. However, a number of successful projects can be used to inform future actions in this area. Barrow Island and Macquarie Island are the two standout projects demonstrating good monitoring techniques to prevent rodent incursions or reinvasions (Greenslade et al., 2013b, Jarrad et al., 2011a, Tasmanian Parks and Wildlife Service, 2010c,

Tasmanian Parks and Wildlife Service, 2014). The principles and techniques used in these two example projects could be adapted, refined and applied to other projects in future.

In relation to action 6.5, again the potential consequences of 'prey switching' or the unintended effect of having a resident predatory animal (whether introduced or native) switch from predating upon introduced rodents to predating on a native species, have not been directly tested in the scientific literature. A few examples of a change in predator from rats to a native species has been observed on Macquarie Island and Anacapa Island in the USA. Knowledge of the risks of changing ecosystem interactions has lead to multi-species approaches for eradication projects such as those employed on the most recent eradication on Macquarie Island (Tasmanian Parks and Wildlife Service, 2014, Tasmanian Parks and Wildlife Service, 2010b). These approaches seem to have been effective at mitigating these unintended impacts to some degree. It could be suggested therefore, that these procedures and techniques should be adopted for other eradication and control projects, where applicable.

While some information gaps have been filled by observations and experience gained through successful projects, research objectives will need to be re-assessed to meet the future information needs of land managers and conservationists. Additionally, a greater emphasis on pre and post eradication monitoring of islands to determine both the positive and negative impacts of current practice, would be beneficial. The continued lack of accumulated knowledge in some areas again demonstrates the case for the development of a best practice eradication and management document for Australia. This document could be used not only to inform and guide land managers designing future projects, but also to identify the gaps in our scientific knowledge of island ecosystem management.

## **Conclusion on the 2009 threat abatement plan**

The review of this TAP has determined that there have been some significant advances in: the techniques, tools, and tactics employed in the eradication of rodents and other conservation actions on islands; the quarantine and surveillance of rodent free islands; and the involvement of island residents and traditional owners in the conservation process. Despite these advances, monitoring of the effects of eradication actions and the sharing of the knowledge gained in completed projects, has not been as successful as could be hoped and a number of priority islands are still affected by invasive rodents. A reprioritisation of islands requiring conservation action based upon best practice information may be needed in the future. In addition, a more concerted emphasis on monitoring and reporting of both successful and failed eradication projects need to be strongly considered in order to improve the outcomes of these projects. Therefore, it is the conclusion of this review that a revised threat abatement plan to reflect these changes will be required to continue to reduce the impact of invasive rodents on the biodiversity of Australia's offshore islands.

## **Looking forward**

During the course of this TAP review, a number of potential future actions to contribute to island conservation and rodent eradication and control work became apparent. These are listed below, and it is proposed that these actions, or adaptations of them, be considered for any future threat abatement activities including a revised TAP, threat abatement advice or similar documents. Proposed actions include:

- Reprioritise the list of islands for conservation action in consultation with states, territories and other relevant stakeholders, including experts.
- Produce a best practice eradication and control manual/ document using experience gained from completed projects (similar to documents produced by NZ DOC and Pacific Islands Initiative etc).
- Emphasise research including baseline studies and monitoring in all future rodent eradication projects on islands to produce a tangible body of evidence for the benefits of island conservation actions.
- Encourage the registration of brodifacoum and other suitable control tools for broad scale use on islands for rodent control with the APVMA.
- Produce a coordinated campaign to promote the benefits of island conservation to the public.
- Encourage the continued engagement with, and involvement of island residents, including Traditional Owners, in the conservation process, at all scales (e.g. actual eradications and control projects, monitoring and surveillance).
- Encourage research into more effective and humane control and eradication tools.
- Continue research into understanding trophic cascades and predator/ prey interactions through the data collected in the baseline studies and monitoring projects on islands with eradications underway.

## APPENDICES

**Appendix A:** Threatened species listed under the EPBC Act or in state/territory legislation (as noted in the tables) that are affected or potentially affected by exotic rodents on islands under 100 000 ha

**Table A1. Listed Australian species that are reported to be threatened by exotic rodents.**

Species	Island	Present (No) Nesting (Yes)	Status
Lord Howe flax snail ( <i>Placostylus bivaricosus</i> )	Lord Howe	Yes	Endangered
Christmas Island thrush ( <i>Turdus poliocephalus erythropleurus</i> )	Christmas	Yes	Endangered
Norfolk Island Green parrot ( <i>Cyanoramphus novaeseelandiae cookii</i> )	Norfolk	Yes	Endangered
Christmas Island Shrew ( <i>Crocidura attenuata trichura</i> )	Christmas	Yes	Endangered
Emerald dove ( <i>Chalcophaps indica natalis</i> )	Christmas	Yes	Endangered
Cockroach ( <i>Panesthia lata</i> )	Lord Howe	Yes	Endangered (NSW)
Lord Howe Island Gecko ( <i>Christinus guentheri</i> )	Lord Howe, Norfolk	Yes	Vulnerable
Lord Howe Island Skink ( <i>Oligosoma lichenigera</i> )	Lord Howe	Yes	Vulnerable
Christmas Island Gecko ( <i>Lepidodactylus listeri</i> )	Christmas	Yes	Vulnerable
Blind snake ( <i>Typhlops exocoeti</i> )	Christmas	Yes	Vulnerable
Golden whistler ( <i>Pachycephala pectoralis xanthoprocta</i> )	Norfolk	Yes	Vulnerable
Scarlet robin ( <i>Petroica m. multicolor</i> )	Norfolk	Yes	Vulnerable
Southern fairy prion ( <i>Pachyptila turtur subantactica</i> )	Macquarie	No	Vulnerable
Grey ternlet ( <i>Procelsterna cerulea</i> )	Lord Howe	No	Vulnerable (NSW)
Little shearwater ( <i>Puffinus assimilis</i> )	Lord Howe	No	Vulnerable (NSW)
Masked booby ( <i>Sula dactylatra</i> )	Lord Howe	No	Vulnerable (NSW)
Providence petrel ( <i>Pterodroma solandri</i> )	Lord Howe, Phillip	Yes	Vulnerable (NSW)
Sooty tern ( <i>Sterna fuscata</i> )	Lord Howe, Norfolk	No	Vulnerable (NSW)
Black-winged petrel ( <i>Pterodroma nigripennis</i> )	Lord Howe	No	Vulnerable (NSW)
White-headed petrel ( <i>Pterodroma lessonii</i> )	Macquarie	No	Vulnerable (Tas)
Wilson's storm petrel ( <i>Oceanites o. oceanicus</i> )	Macquarie	No	Vulnerable (Tas)

**Table A2. Listed Australian endemic and native species that are not specifically reported to be threatened by exotic rodents present on the island but may benefit indirectly from their removal**

Species	Island	Present (No) Nesting (Yes)	Status
Christmas Island Goshawk ( <i>Accipiter fasciatus natalis</i> )	Christmas	Yes	Endangered
Norfolk Island Boobook ( <i>Ninox novaeseelandiae undulata</i> )	Norfolk	Yes	Endangered
Southern giant petrel ( <i>Macronectes giganteus</i> )	Macquarie	No	Endangered
Northern giant petrel ( <i>Macronectes halli</i> )	Macquarie	No	Vulnerable
Lord Howe Woodhen ( <i>Gallirallus sylvestris</i> )	Lord Howe	Yes	Vulnerable
Lord Howe Island Currawong ( <i>Strepera graculina crissalis</i> )	Lord Howe	Yes	Vulnerable
Christmas Island Frigate bird ( <i>Fregata andrewsi</i> )	Christmas	No	Vulnerable
Christmas Island Hawk owl ( <i>Ninox natalis</i> )	Christmas	Yes	Vulnerable
Black-browed albatross ( <i>Thalassarche melanophris</i> )	Macquarie	No	Vulnerable
Grey-headed albatross ( <i>Thalassarche chrysostoma</i> )	Macquarie	No	Vulnerable
Wandering albatross ( <i>Diomedea exulans</i> )	Macquarie	No	Vulnerable
Light-mantled albatross ( <i>Phoebastria palpebrata</i> )	Macquarie	No	Vulnerable

**Table A3. Listed Australian species that occur on rodent-free islands but that are likely to be threatened (to various extents) if exotic rodents invade and establish**

Species	Island	Present (No) Nesting (Yes)	Status
Phasmid ( <i>Dryococelus australis</i> )	Islets off Lord Howe	Yes	Critically endangered
Round Island petrel ( <i>Pterodroma arminjonata</i> )	N. Keeling	No	Critically endangered
Herald petrel ( <i>Pterodroma heraldica</i> )	Raine (Coral Sea)	No	Critically endangered
Buff-banded rail ( <i>Gallirallus philippensis andrewsi</i> )	North Keeling	Yes	Endangered
Gould's petrel ( <i>Pterodroma l. leucoptera</i> )	Cabbage Tree	Yes	Endangered
Antarctic tern ( <i>Sterna vittata vittata/ bethunei</i> )	Heard, Stacks off Macquarie	No	Endangered
Bramble Cay melomys ( <i>Melomys rubicola</i> )	Bramble Cay	Yes	Endangered
Western barred bandicoot ( <i>Perameles b. bougainville</i> )	Bernier, Dorre, Faure	Yes	Endangered
Kermadec petrel ( <i>Pterodroma n. neglecta</i> )	Islets off Lord Howe	No	Vulnerable
Species	Island	Only found or nests on the island(s)	Status
Blue petrel ( <i>Halobaena caerulea</i> )	Stacks off Macquarie	No	Vulnerable
Flesh-footed shearwater ( <i>Puffinus carneipes</i> )	Islets off Lord Howe	No	Vulnerable
Burrowing bettong ( <i>Bettongia lesueur</i> )	Boodie	Yes	Vulnerable
White-bellied storm petrel ( <i>Fregetta g. grallaria</i> )	Islets off Lord Howe	No	Vulnerable
Golden bandicoot ( <i>Isodon auratus barrowensis</i> )	Barrow	Yes	Vulnerable
Spectacled hare wallaby ( <i>Lagorchestes c. conspicillatus</i> )	Barrow	Yes	Vulnerable
Barrow Island euro ( <i>Macropus robustus isabellinus</i> )	Barrow	Yes	Vulnerable
Rufous hare wallaby ( <i>Lagorchestes hirsutus bernieri</i> )	Bernier	Yes	Vulnerable
Rufous hare wallaby ( <i>Lagorchestes hirsutus dorrae</i> )	Dorre	Yes	Vulnerable
Worm lizard ( <i>Aprasia r. rostrata</i> )	Hermite	Yes	Vulnerable
Airlie Island ctenotus ( <i>Ctenotus angusticeps</i> )	Airlie	Yes	Vulnerable
Lancelin skink ( <i>Ctenotus lancelini</i> )	Lancelin	Yes	Vulnerable
Spiny-scale skink ( <i>Egernia stokesii aethiops</i> )	Baudin	Yes	Vulnerable
Lesser noddy ( <i>Anous tenuirostris melanops</i> )	Pelsaert, Wooded, Morlay	Yes	Vulnerable
Cape Barren goose ( <i>Cereopsis novaehollandiae grisea</i> )	Recherche Archipelago	No	Vulnerable
Recherche rock wallaby ( <i>Petrogale lateralis hacketti</i> )	Mondrian, Wilson, Westall	Yes	Vulnerable
Pearson rock wallaby ( <i>Petrogale lateralis pearsonii</i> )	Pearson, Thistle, Wedge	Yes	Vulnerable
Imperial shag ( <i>Leucocarbo atriceps nivalis</i> )	Heard	Yes	Vulnerable
Fairy wren ( <i>Malurus leucopterus edouardi</i> )	Barrow	Yes	Vulnerable
Fairy wren ( <i>Malurus l. leucopterus</i> )	Dirk Hartog	Yes	Vulnerable
Soft-plumage petrel ( <i>Pterodroma mollis deceptornis</i> )	Maatsuyker	No	Vulnerable
Shy albatross ( <i>Thalassarche cauta</i> )	Albatross, Mewstone, Pedra Blanca	No	Vulnerable

## **Appendix B: Macquarie Island additional information**

### **History:**

Multiple pest species have been introduced to Macquarie Island in the sub-Antarctic. Dogs and cats were recorded as present in 1820 (Robinson and Copson 2014), weka (a New Zealand rail) and rabbits in 1870, and ship rats and mice in 1890; although the latter two species are likely to have been present before this time due to the presence of sealers on the island.

Pest control efforts have been pursued on Macquarie Island since 1968 and have addressed all the species introduced to the island. These efforts have included the eradications of wekas in 1988 (the last individual was shot in 1988) and of cats between 1975 and 2000 (with the last cat on the island shot in June of 2000). Ongoing monitoring for both these species has confirmed their eradication from the island (Robinson and Copson 2014). Despite the removal of these two species, rabbits, ship rats and house mice have persisted on Macquarie Island and have had significant impacts upon the flora, fauna, landscape, and overall ecosystem health of the island. Due to these serious effects, all three of these species have been subject to an eradication programme in more recent years (since 2005).

### **Challenges:**

The eradication program faced many challenges. Some of these included the remoteness of the island (with its location in the sub-Antarctic) and the logistical challenge of transporting the necessary equipment and personnel in order to undertake the various phases of the eradication programme. In order to successfully achieve the transport phase of the eradication, the project managers needed to take into account both the remoteness of the island and the often inhospitable weather conditions experienced during winter (the optimum time for baiting) (Tasmanian Parks and Wildlife Service, 2010a).

Another challenge was the size and the topography of the island which, based on prior experiences in island eradication operations, was determined to require the island be baited in its entirety using aerial deployment of brodifacoum-based cereal pellet baits. The use of alternative control methods were considered unlikely to be effective for anything more than localised control of rodent species (Mac Island Eradication Plan- Part A-Overview) due to the large size of the island and the difficult terrain. However, these methods were considered as supplementary options for the eradication program as baiting was not considered likely to be 100% effective.

The island was split into a number of priority areas to be aurally baited according to the likelihood of these areas to contain populations of the target species, the benefit to native species (such as the royal penguin colony in at the south end of the island) and the difficulty in accessing these areas for aerial baiting (turbulence, cloud and wind effects) (Tasmanian Parks and Wildlife Service, 2010b).

The baiting programme involving aerial baiting with brodifacoum cereal pellets was tailored to ensure that it posed the best possible chance of eradicating each of the three target species.

Based on prior experience in the eradication of these species, it was determined that ship rats would likely be the most susceptible to the aerial baiting programme and would likely be mostly (if not wholly) eradicated after the first bait drop. Therefore, the program did not require specific measures to ensure their eradication.

House mice are known to be more resistant to the aerial baiting technique, particularly in the presence of ship rats. There are a number of theories as to why this is the case, but it is broadly accepted in the literature that this is due to competition between rats and mice for the baits after distribution. The solution proposed for this in the Macquarie Island eradication plan, was to ensure that a high density of bait was distributed to maximise exposure and ensure sufficient and lethal amounts of bait could be taken by the mice, regardless of competition from the ship rats. Additionally, a second bait drop was suggested (based upon previous experience) to ensure that any remaining mice would receive sufficient exposure to the baits to receive a lethal dose.

Rabbits were considered to be the most difficult of the three species to eradicate, despite being highly susceptible to the chosen bait and technique. Previous attempts to eradicate rabbits in the literature suggested that although the majority of the population would likely be removed by the two baiting drops, it was likely that a small remnant population would survive. To combat this, calici virus (the causative virus of rabbit hemorrhagic disease) was released on the island via dosed carrots in January 2011 to significantly reduce rabbit numbers prior to the baiting drops. This tactic was remarkably effective and is estimated to have reduced the rabbit population by as much as 90% (Mac island 2013 project update- Tas PWS). In addition to these measures, the rabbit population was made the initial focus of a monitoring and hunting programme immediately following the bait drops in 2011. This ensured that any residual rabbit populations were rapidly detected and removed (Tasmanian Parks and Wildlife Service, 2010a).

#### **Baiting operation:**

The bait drop operation was initially intended to be completed in the winter of 2010 (May to August), but was delayed, and eventually cancelled, by adverse weather conditions. Despite the cancellation, a small portion of the island (about 8%) was successfully baited during this period. The baiting was very successful in killing the target species within the 8% covered; however there was some anticipated incidental mortality of non-target seabirds after the application of bait in June 2010 (Tasmanian Parks and Wildlife Service, 2014).

A total of 960 dead birds including brown and south polar skuas, kelp gulls, two species of duck (black and mallard) and giant petrels – both northern and southern were discovered following the cancelled baiting season. These bird deaths were either confirmed or presumed to be as a result of brodifacoum poisoning from the baiting drop. Following this, a review of the project by both the Tasmanian and Commonwealth governments recommended that the eradication project continue in 2011, but with the introduction of additional mitigation measures to reduce the mortality rates of non-target species. The most significant mitigation measure proposed was the introduction of calici virus in order to reduce the size of the rabbit population before beginning the aerial baiting.

The second baiting season between May and July of 2011 comprised of two whole-of-island bait drops and a third bait drop to target high risk areas such as rock stacks and the penguin colonies on the south of the island. This delayed program began on the 3rd May 2011 and was finished on schedule within seven weeks. In order to further mitigate the risk of secondary poisoning to scavenging seabirds the project staff conducted follow-up manual collection and disposal of poisoned carcasses during the baiting period (Tasmanian Parks and Wildlife Service, 2014).

On the completion of the bait drops and cleanup operations in 2011, the monitoring phase of the project was immediately initiated in July of 2011. This phase involved trained field teams



being deployed to locate and kill any remaining rabbits, rats or mice that may have survived the baiting programme. This involved shooting and spotlighting, fumigating burrows, the use of specially trained hunting dogs, and a trapping schedule to search for remnant rodents. The monitoring programme was concluded in the second half of 2013 with no signs of any of the three target rodent species detected; in fact no rats had been detected on the island since May 2011, and no mice or rabbits had been detected since June 2011. As a result, in April 2014, Macquarie Island was declared pest free, bringing this highly successful eradication programme to a close (Department of the Environment, 2014a)

## REFERENCES:

- APVMA. 2014. *Permits database* [Online]. Australia: Australian Pesticides and Veterinary Medicines Authority, Australia. Available: <http://www.apvma.gov.au/> [Accessed 14/04/01 2014].
- AUSTRALIAN ANTARCTIC DIVISION. 2012. *Australian Antarctic Division- Cargo and Freight* [Online]. Department of the Environment- Australian Antarctic Division. Available: <http://www.antarctica.gov.au/living-and-working/travel-and-logistics/cargo-and-freight> [Accessed 21/07/2014 2014].
- AUSTRALIAN DEPARTMENT OF AGRICULTURE. 2014. *Rodents on Vessels* [Online]. Canberra, ACT, Australia: Australian Department of Agriculture. Available: <http://www.daff.gov.au/biosecurity/avm/vessels/fact-sheets/rodents> [Accessed 22/07 2014].
- BERGSTROM, D. M., LUCIEER, A., KIEFER, K., WASLEY, J., BELBIN, L., PEDERSEN, T. K. & CHOWN, S. L. 2009a. Indirect effects of invasive species removal devastate World Heritage Island. *Journal of Applied Ecology*, 46, 73-81.
- BERGSTROM, D. M., LUCIEER, A., KIEFER, K., WASLEY, J., BELBIN, L., PEDERSEN, T. K. & CHOWN, S. L. 2009b. Management implications of the Macquarie Island trophic cascade revisited: a reply to Dowding et al. (2009). *Journal of Applied Ecology*, 46, 1133-1136.
- BROOME, K., COX, A., GOLDING, C., CROMARTY, P., BELL, P. & MCCLELLAND, P. 2014. Rat eradication using aerial baiting Current agreed best practice used in New Zealand. *In: NEW ZEALAND DEPARTMENT OF CONSERVATION* (ed.). Wellington, New Zealand.: New Zealand Department of Conservation,
- CARING FOR OUR COUNTRY. 2009. *The eradication of exotic rodents from several WA islands with significant conservation values* [Online]. Available: <http://www.nrm.gov.au/projects/open-call/wa/rodent-eradication-wa/> [Accessed 12/08 2014].
- CAUT, S., ANGULO, E. & COURCHAMP, F. 2009. Avoiding surprise effects on Surprise Island: alien species control in a multitrophic level perspective. *Biological Invasions*, 11, 1689-1703.
- CHEVRON AUSTRALIA. 2010. Barrow Island Quarantine: Terrestrial and Marine Quarantine Management System. [Accessed 22/07/2014].
- CORY, F., WILSON, A., PRIDDEL, D., CARLILE, N. & KLOMP, N. 2011a. Eradication of the House Mouse (*Mus musculus*) from Montague Island, New South Wales, Australia. *Ecological Management & Restoration*, 12, 102-109.
- CORY, F., WILSON, A., PRIDDEL, D., CARLILE, N. & KLOMP, N. 2011b. Eradication of the House Mouse (*Mus musculus*) from Montague Island, New South Wales, Australia. *Ecological Management & Restoration*, VOL 12 102-109.
- DEPARTMENT OF THE ENVIRONMENT. 2014a. *Media release, 7/04/2014*, [Online]. Canberra, ACT: the Department of the Environment,. Available: <http://www.environment.gov.au/minister/hunt/2014/mr20140407.html> 2014].
- DEPARTMENT OF THE ENVIRONMENT. 2014b. *Working on Country*, [Online]. Australian Department of the Environment,. Available: <http://www.environment.gov.au/indigenous/workingoncountry/index.html> [Accessed 17/04/2014].
- DIRECTOR OF NATIONAL PARKS 2010. Norfolk Island Region Threatened Species Recovery Plan. *In: DEPARTMENT OF THE ENVIRONMENT, W., HERITAGE AND THE ARTS*, (ed.). Canberra: National Parks and Wildlife Service,.
- EASON, C., HENDERSON, R., HIX, S., MACMORRAN, D., MILLER, A., MURPHY, E., ROSS, J. & OGILVIE, S. 2010. Alternatives to brodifacoum and 1080 for possum and rodent control—how and why? *New Zealand Journal of Zoology*, 37, 175 - 183.

- ECOSURE 2009. Prioritisation of high conservation status of offshore islands. *Report to the Australian Government Department of the Environment, Water, Heritage and the Arts*. 19/08/2009 ed.
- GREENSLADE, P. A., BURBIDGE, A. A. & LYNCH, A. J. J. 2013b. Keeping Australia's islands free of introduced rodents: the Barrow Island example. *Pacific Conservation Biology* 19, 284–294.
- GREGORY, S., HENDERSON, W., SMEE, E. & CASSEY, P. 2014. Eradications of vertebrate pests in Australia: A review and guidelines for future best practice. *PestSmart Toolkit publication, Invasive Animals Cooperative Research Centre, Canberra, Australia*, 90.
- GRIFFITHS, R. 2011. Targeting multiple species – a more efficient approach to pest eradication In: Veitch, C. R.; Clout, M. N. and Towns, D. R. (eds.). 2011. Island invasives: eradication and management. IUCN, Gland, Switzerland, pp.172-176. In: VEITCH, C. R., CLOUT, M. N. & TOWNS, D. R., eds. Island invasives: eradication and management., IUCN., 2011 2011 Gland, Switzerland. IUCN, 536.
- HARPER, G. A. & CABRERA, L. F. 2010. Response of mice (*Mus musculus*) to the removal of black rats (*Rattus rattus*) in arid forest on Santa Cruz Island, Galápagos. *Biological Invasions*, 12, 1449-1452.
- HOWALD, G., DONLAN, C. J., GALVÁN, J. P., RUSSELL, J. C., PARKES, J., SAMANIEGO, A., WANG, Y., VEITCH, D., GENOVESI, P., PASCAL, M., SAUNDERS, A. & TERSHY, B. 2007. Invasive Rodent Eradication on Islands
- Erradicación de Roedores Invasores de Islas. *Conservation Biology*, 21, 1258-1268.
- ISLAND ARKS AUSTRALIA. Island Arks Symposium III. In: BALL, D., BRYANT, S., BELL, C., DREW, L., SUE, R. & JUSTINE, S., eds. Island Arks Symposium III, 11-13 February, 2014. 2014 Hobart, Tasmania, Australia.
- ISLAND CONSERVATION. 2014. *Database of Island Invasive Species Eradications* [Online]. New Zealand: Island Conservation. Available: <http://eradicationfdb.fos.auckland.ac.nz> 2014].
- JARRAD, F. C., BARRETT, S., MURRAY, J., PARKES, J., STOKLOSA, R., MENGERSEN, K. & WHITTLE, P. 2011a. Improved design method for biosecurity surveillance and early detection of non-indigenous rats. *New Zealand Journal of Ecology* 35, 132-144.
- KEITT, B., GRIFFITHS, R., BOUDJELAS, S., BROOME, K., CRANWELL, S., MILLETT, J., PITT, W. & SAMANIEGO-HERRERA, A. Best practice guidelines for rat eradication on tropical islands. *Biological Conservation*.
- LANDCARE AUSTRALIA. 2011. *The Mice of Mer* [Online]. Canberra, ACT: Landcare Australia. Available: <http://www.nrm.gov.au/projects/open-call/qld/exotic-rodent-eradication/> [Accessed 30/07 2014].
- LANDOS, J. 2003. Quarantine Strategy For Lord Howe Island. Lord Howe Island: Lord Howe Island Board,.
- LEUNG, L. 2013. Final Project Report - Eradication of exotic rodents on Mer Island Torres Strait. In: CARING FOR OUR COUNTRY PROGRAM, D. O. A., FISHERIES AND FORESTRY, (ed.). University of Queensland,.
- LORD HOWE ISLAND BOARD 2009. Draft Lord Howe Island Rodent Eradication Plan. *Lord Howe Island Board, Lord Howe Island*.
- LORD HOWE ISLAND BOARD. 2014. *Quarantine* [Online]. Lord Howe Island, NSW. Available: <http://www.lhib.nsw.gov.au/environment/protection-of-the-environment/quarantine> [Accessed 23/07 2014].
- MCLEOD, L. & SAUNDERS, G. 2013. Pesticides used in the management of Vertebrate Pests in Australia: A Review. In: NSW, D. O. P. I. (ed.). Department of Primary Industries NSW.
- MOORE, J. L., ROUT, T. M., HAUSER, C. E., MORO, D., JONES, M., WILCOX, C. & POSSINGHAM, H. P. 2010. Protecting islands from pest invasion: optimal allocation of biosecurity resources between quarantine and surveillance. *Biological Conservation*, 143, 1068-1078.
- MORRIS, K. 2011. The eradication of the black rat (*Rattus rattus*) on Barrow and adjacent islands off the North-West coast of Western Australia.

- NATIONAL PARKS AND WILDLIFE SERVICE NSW 2009. Muttonbird Island Nature Reserve Plan of Management. *In*: NSW, D. O. E. A. C. C. (ed.). Department of Environment and Climate Change NSW.
- PACIFIC ISLANDS INITIATIVE 2011. Resource Kit for Rodent and Cat Eradication. 2011 ed.: Pacific Islands Initiative,.
- PRIDDEL, D., CARLILE, N., WILKINSON, I. & WHEELER, R. 2011. Eradication of exotic mammals from offshore islands in New South Wales, Australia. *In*: NSW, O. O. E. A. H. (ed.). Office of Environment and Heritage NSW.
- QUEENSLAND PARKS AND WILDLIFE SERVICE 2013. Great Barrier Reef Coastal Zone Strategic Assessment. *In*: QUEENSLAND DEPARTMENT OF STATE DEVELOPMENT INFRASTRUCTURE AND PLANNING (ed.). Brisbane, Queensland: Queensland Department of State Development Infrastructure and Planning,.
- SECRETARIAT OF THE PACIFIC REGIONAL ENVIRONMENT PROGRAMME 2009. Guidelines for Invasive Species Management in the Pacific; A Pacific strategy for managing pests, weeds and other invasive species,. Apia, Samoa: Secretariat of the Pacific Regional Environment Programme.
- SPRINGER, K. 2011. Planning processes for eradication of multiple pest species on Macquarie Island – an Australian case study. *In*: VEITCH, C. R., CLOUT, M. N. & TOWNS, D. R. (eds.) *Island invasives: eradication and management*. Gland, Switzerland. IUCN.
- TASMANIAN PARKS AND WILDLIFE SERVICE 2010c. Macquarie Island Pest Eradication Plan- Part F- Monitoring Plan. Department Of Primary Industries, P., Water And Environment, Hobart, Tasmania.
- TASMANIAN PARKS AND WILDLIFE SERVICE 2013. Monitoring and Reporting System for Tasmania's National Parks and Reserves- Macquarie Island Pest Eradication Project. Department Of Primary Industries, P., Water And Environment, Hobart, Tasmania.
- TASMANIAN PARKS AND WILDLIFE SERVICE 2014. Macquarie Island Pest Eradication Project - Evaluation Report August 2014. Department Of Primary Industries, P., Water And Environment, Hobart, Tasmania.
- TASMANIAN PARKS AND WILDLIFE SERVICE 2010a. Macquarie Island Pest Eradication Plan Part A – Overview. Department Of Primary Industries, P., Water And Environment, Hobart, Tasmania.
- TASMANIAN PARKS AND WILDLIFE SERVICE 2010b. Macquarie Island Pest Eradication Plan Part B – Operational Plan. 76. Department Of Primary Industries, P., Water And Environment, Hobart, Tasmania.
- TERAUDS, A., DOUBE, J., MCKINLAY, J. & SPRINGER, K. 2014. Using long-term population trends of an invasive herbivore to quantify the impact of management actions in the sub-Antarctic. *Polar Biology*, 1-11.
- VEITCH, C., CLOUT, M. & TOWNS, D. E. I. I. E. A. M. I., GLAND, SWITZERLAND. 2011. Island invasives: eradication and management. *In*: VEITCH, C., CLOUT, M. & TOWNS, D., eds. *Island invasives: eradication and management*, 2011 Gland, Switzerland. 537.
- WHITWORTH, D. L., CARTER, H. R. & GRESS, F. 2013. Recovery of a threatened seabird after eradication of an introduced predator: Eight years of progress for Scripps's murrelet at Anacapa Island, California. *Biological Conservation*, 162, 52-59.