Australian Government
Department of the Environment, Water, Heritage and the Arts

BACKGROUND DOCUMENT for the
THREAT ABATEMENT PLAN
to reduce the impacts of exotic rodents on biodiversity on Australian offshore islands of less than 100 000 hectares

2009

Contents

1 Introduction

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 a threat abatement plan (hereafter the plan) for rats and mice on islands less than 100 000 ha in area. This document aims to provide the detailed information to underpin a threat abatement plan (Commonwealth of Australia 2008).

Exotic mammals, and particularly rodents, have been a major cause of extinction and decline of island biodiversity around the world (Towns *et al*. 2006), and indeed the majority of extinctions over the last millennium have been of species on islands (Groombridge 1992). 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.

One or more of the four exotic rodents (ship rats, Norway rats, Pacific rats, and house mice) are reported to be present on 140 islands, 133 under 100 000 ha, of the over 8300 islands in Australia. They also have the potential to invade many of the islands that are currently thought to be free of exotic rodents.

2 The problem with exotic rodents

2.1 Rodent species on Australian islands

Body weights and lengths overlap for the four species of exotic rodents when juveniles are considered, but they can be distinguished using morphological characters (Table 2.1). Additionally they can be distinguished from skull characteristics or genetic profiling. Native Australian rodents in the genera *Melomys*, *Zyzomys*, *Pseudomys*, *Leggadina* and *Rattus* may also be present on islands. This complicates confirming the presence or absence of exotic rodents, and presents additional non-target problems for control programs.

2.1.1 Ship rat (*Rattus rattus*)

The ship, or black, rat is common around most of the Australian coast, reaching highest numbers near human habitation, though also found in uninhabited areas. It has not penetrated into the central region of Australia, probably due to a combination of lack of water and competition from native rodents, despite earlier fears that native rodents may be displaced. However, it does live on arid and semi-arid islands in the north of Australia.

Ship rats have an unresolved taxonomy consisting of a complex containing *R. rattus*, *R. tanezumi* and *R. mansorius* and possibly other 'species' (Aplin *et al*. 2003). The European form is most widely distributed around the world (including Australia), though the Asian form (with a different number of chromosomes) has been found in Brisbane.

In Australia, ship rats can have up to six litters of 5–10 young per litter each year, with a 21–22 day gestation time. Juveniles are weaned by 20 days of age, and are reproductively mature by 3–4 months. This can lead to rapid population expansion in suitable environments, although ship rats rarely live longer than one year in the wild.

Ship rats are adept swimmers and will cross channels hundreds of metres in width. In New Zealand ship rats have colonised islands over 500 m offshore. They are also the most arboreal of the exotic rodents.

2.1.2 Norway rat (*Rattus norvegicus*)

The Norway, or brown, rat is only found in coastal areas of Australia with major human habitation. Norway rats are colonial, generally ground-dwelling, and prefer wetter habitats (e.g. riparian zones). Like ship rats they are widely omnivorous, though they also utilise marine intertidal habitats.

In Australia female Norway rats can have up to 18 young in a litter, but usually only 7–10, with a gestation period of 21–23 days. Juveniles are weaned by 20 days, and are reproductively active by 3–4 months. In colder habitats (e.g. on subantarctic islands) brown rats rarely live for more than a year, though in temperate zones they can live for 2–3 years.

Norway rats are very capable swimmers and will easily swim to islands up to 2 km from mainlands. Water is not seen as a barrier to routine movements of individuals within their home-range. Laboratory studies suggest that swimming ability is a learnt behaviour, and that water temperature variability across Australia would have little effect on swimming ability.

2.1.3 Pacific rat (*Rattus exulans*)

The Pacific or Polynesian rat is only found on a few islands in northern Australia, although it has been a successful invader in the Pacific region, having colonised with early Polynesians. It is usually dominated by the two other introduced rat species.

Pacific rats have litter sizes of between two and nine, with a gestation period of 10–21 days. Females produce three litters per year on average. Juveniles are weaned at about 4 weeks, but do not usually breed in their season of birth. They reach maturity at about 8–12 months.

Pacific rats have limited swimming ability, and are not expected to be capable of crossing channels more than 200 m wide.

2.1.4 House mouse (*Mus musculus*)

The house mouse is a complex of four subspecies, at least two of which, *M. m. musculus* and *M. m. domesticus* (and perhaps a third *M. m. castaneus*), reached Australia with European settlers. Morphologically, Australian mice (like those in New Zealand) are mostly of the *domesticus* form, but their genetic complexity argues for placing them as *M. musculus* (Singleton and Redhead 1990).

Mice are a major agricultural pest distributed across all of Australia, reaching plague proportions in some years in eastern and southern rangelands. In Australia mice breed opportunistically and usually have litter sizes of four to eight, with a 19-day gestation time, and young reach reproductive maturity by 8 weeks. During plague years mice probably impact other small native rodents through competition. Outside plague-years mice often become undetectable in the landscape. This cryptic behaviour has implications for detecting reinvaders and eradication survivors.

Mice may attempt to cross waterways, particularly when they are at high densities; however, they are not generally considered proficient swimmers. Most studies of mouse swimming ability have found poor orientation and movement.

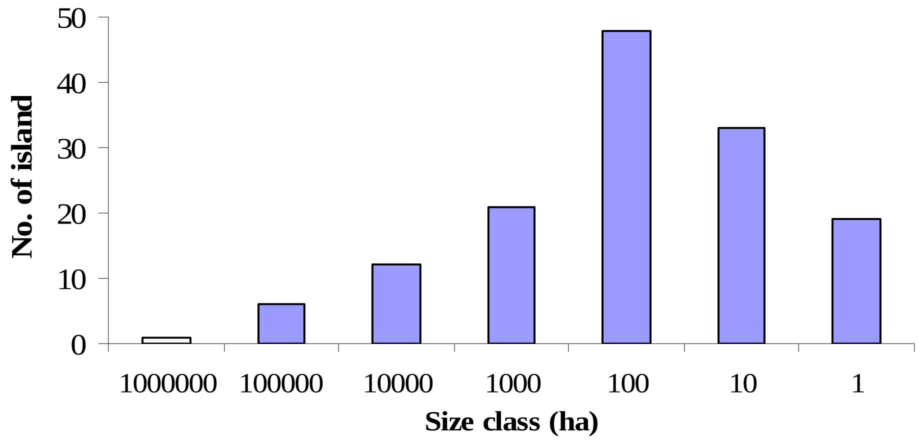
2.2 Australian islands with rodents

Australia has over 8300 islands (Table 2.2) of which at least 133 of those under 100 000 ha are reported to have one or more species of exotic rodents (Table 2.3). To date 40 populations of exotic rodents (on 39 islands) have been eradicated (Table 2.4).

Ship rats and mice are widespread on the mainland of Australia, mice being almost ubiquitous while ship rats are largely absent from semi-arid areas and the wet-dry tropics (Caughley *et al.* 1998). Norway rats are largely restricted to urban areas while Pacific rats are thought to be absent from the mainland. These distributions are reflected on islands with ship rats and mice being the most common species, often occurring together (Table 2.5).

The 140 islands known to have exotic rodents range in size from <1 ha up to 6 million hectares for Tasmania (Table 2.2; Fig. 2.1). Of those less than 100 000 ha (the cut-off size for this plan) rodents remain on at least 133 with a total area of 338 800 ha. Costs to eradicate rodents will vary greatly for each island independent of its size according to its remoteness and how local constraints must be managed (Donlan and Wilcox 2007). However, at an estimated average cost of $200/ha to eradicate rodents it would cost $68 million to clear all exotic rodents from all islands less than 100 000 ha – assuming each is feasible. This is logically approached by prioritising the islands and allocating strategies suited to the unique circumstances of each. This could be done nationally if state and territory governments agreed, although it is likely that each have different perceptions and needs on the factors important in any ranking system. However, this background document attempts to 'catalogue' the information and best practice upon which such decisions can be made.

Figure 2.1: Number of Australian islands in different size classes that have exotic rodents



About 16% of the islands with exotic rodents are joined to the adjacent mainland by mudflats, mangrove swamps, tombolos (or sand bars), causeways, or bridges, and a further 15% are within 500 m of adjacent mainlands, and thus within easy swimming distance for ship and Norway rats. A different solution will be required for these islands than for remote islands – at least for any ongoing quarantine systems should eradication be attempted.

Of all the islands with rodents, about 57% are entirely or substantially managed under various types of reserved tenures (e.g. national parks, conservation areas), 9% are owned by Aboriginal people, and the rest are either Crown-lease or private tenures. Overall planning for Crown-owned island management is further complicated in most jurisdictions because several agencies operating under different legislation have responsibility for managing islands.

Elsewhere in the world rodents have been eradicated from about 350 islands (Howald *et al*. 2007) (Table 2.6). However, sympatric ship rats and mice have been eradicated from only six islands worldwide: Barrow, in Western Australia, where they were present in separate and small parts of the island, Flat (253 ha in Mauritius), Rasa (60 ha in Mexico), Motutapere (46 ha in New Zealand), Surprise (24 ha in New Caledonia), and White Cay (15 ha in the Bahamas). Attempts against both species on Denis and Bird islands in the Seychelles failed to remove one or the other. This may be a complexity for the 22 Australian islands known to have both species because effective control of the rats may release the mice from competitive pressure despite the losses they suffer (Caut *et al*. 2007).

2.3 Impacts of exotic rodents on island biodiversity and economic well-being

Islands are important places for Australian biodiversity. The continental islands represent examples of mainland ecosystems that are generally less impacted by disturbances such as fire and grazing, and many are still free of introduced plants and animals. Some of these islands are also refuges for plant and animal species that are either rare or extinct on the mainland. The remote oceanic islands have high degrees of endemism and thus comprise unique evolutionary units. Both continental and oceanic islands can be key breeding sites for marine birds, turtles and seals.

Nine species of mammal now survive only on Australia's islands, without which they would have added to the 19 mammal species already extinct in Australia in the last 200 years (Burbidge *et al*. 1997). There are also several subspecies of vertebrates that only occur on islands. Together, these island populations provide opportunities for fauna recovery programs on the mainland by providing founder stock for translocation to areas where the threats have been controlled. Islands also provide secure sites or arks to hold species under current threat of extinction on the mainland, e.g. the mala (*Lagorchestes hirsutus*) (Burbidge *et al*. 1999).

Seven lines of evidence together prove that exotic rodents have caused or may cause native species or ecological communities to become eligible for inclusion in a threatened list, or cause a listed species or community to become more endangered, or adversely affect two or more listed threatened species or ecological communities. These are the criteria for a process to be listed as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). In fact, exotic rodents on islands meet all three criteria.

1. *Diet*: All four invasive rodents are omnivorous, eating most plant parts, insects, molluscs, snails, reptiles and their eggs, birds and their eggs, and other animals, sometimes much larger than themselves (e.g. mice predating albatross chicks on Gough Island in the Atlantic Ocean; Wanless *et al.* 2007). Exotic rodents also eat the seeds and fruit of native plants and potentially limit regeneration of some species (Caughley *et al*. 1998). They may also compete with native species such as the rodents and marsupials that occupy the same niche as exotic rodents on many Australian islands. So their diet alone provides *a priori* evidence that they may affect native biodiversity.
2. *Disease*: Ship rats (and mice) have also been implicated in the extinction of the native Christmas Island rats (*Rattus macleari* and *R. nativitatus*) by introducing diseases – as well as by hybridisation (Pickering and Norris 1996).
3. *Extinction*: Stronger evidence of impacts comes from the coincidence between the arrival of rats on islands and the extinction (loss of the entire species) of native animals. At least 20 species or subspecies of Australian animals endemic to a particular island became extinct after the arrival of exotic rodents (Table 2.7).
4. *Extirpation*: The arrival of rodents also caused the extirpation (loss from that island) of many species. At least seven species listed as threatened have been extirpated from at least one Australian island (Table 2.8).
5. *Decline*: The abundance of many species, including some listed as threatened (see appendix A in the Threat Abatement Plan), has declined on Australian islands in the presence of exotic rodents. On continental islands in Western Australia ship rats have been implicated in the decline and extirpation of native mammals (Morris 2002, Burbidge and Manly 2002).
6. *Ecosystem change*: Rodents also cause more-complex indirect effects when these have involved changes in species that 'engineer' the ecosystem – such as seabirds (Fukami *et al*. 2006).
7. *Interaction with other pests*: Exotic rodents may also impact native biodiversity by acting as the primary prey for other exotic predators such as feral cats or foxes. That is, the abundance of rodents determines the abundance of predators, which in turn also prey on native animals and can drive these to extinction (e.g. Pech *et al*. 1995).

Forty-two percent of the islands with exotic rodents also have exotic mammalian predators (feral cats, foxes or ferrets) (Table 2.3). Attempts to eradicate rodents from these islands should plan to eradicate the predators as part of the restoration process in case removal of the rodents alone causes an increase in predation on native prey.

Twenty percent of the islands also have rabbits that might also be eradicated as part of any rodent eradication plan, especially if aerial poisoning is the method chosen.

Judging by the evidence in Tables 2.7 and 2.8 in this report, ship rats are the worst rodent threat on Australian islands. For example, five species of endemic birds that persisted for decades with mice became extinct on Lord Howe Island after the arrival of ship rats in 1918. However, the effect of mice has been more subtle as they have not had such catastrophic effects on avian species. Mice are efficient predators of invertebrates (particularly spiders) and may have been the cause of extirpation of several insects from Lord Howe Island (Hutton et al. 2007), and on the subantarctic Antipodes Islands. (Marris 2000).

Exotic rodents are also a social and economic pest on islands inhabited by people. For example, the palm seed horticultural industry on Lord Howe Island would benefit by over $5 million over 30 years if the ship rats could be eradicated (Parkes *et al*. 2004).

3 Management of the threat

3.1 A response framework

The Threat Abatement Plan aims provide a national approach to management, research and education on exotic rodents on islands in three objectives:

- *Removal* of the threat by eradicating the rodents where this is feasible
- *Mitigation* of the threat where eradication is not feasible by efficient and effective sustained control of the rodents, and
- *Reduction* of the risks of invasion or reinvasion of rodents onto islands where they do not occur or have been eradicated.

The documented successes in rodent eradication on islands around the world and in Australia demonstrate that achieving the first of the broad aims is already technically possible for more Australian islands. This Background Document sets out the conditions that have to be considered to identify where eradication is feasible and/or what research, policy, or management actions need to be done to make it so. Achieving the second aim on islands where eradication is not possible is more difficult. The tools to sustain control are available, but the strategy requires ongoing commitment at frequencies and intensities of control that are not always clear. Government agencies may find it difficult to sustain control in the face of these biological uncertainties and/or without the active participation of island residents, where these occur. Achieving the third aim also requires ongoing commitment, and the tools and strategies to do it efficiently and effectively are being developed.

Nevertheless, **management of exotic rodents on Australian islands is a tractable problem with clear and simple measures of progress**. Thus, there are no technical or logistical reasons why the aims of the Threat Abatement Plan should not be achieved for the most important islands over the next decade or so at modest cost.

3.2 Setting priorities

Setting priorities for action has to be considered when funding is insufficient to do everything at once. The main question is which islands should be treated first? The answer is simple at one level – those on which removal of exotic rodents would provide the greatest benefit to biodiversity. The key oceanic islands of Lord Howe, Norfolk, Macquarie, Christmas, and the southern Cocos/Keeling islands would rank highest on this simple criterion because they all have exotic rodents that threaten species listed under various Commonwealth or State/Territory laws (see Tables 2.7 and 2.8 in this report and Appendix A in the Threat Abatement Plan).

However, the practicalities of setting annual budgets to work through priority actions also need to take account of both priority baseline needs (e.g. for priority quarantine and sustained control) and the one-off and variable costs for eradication projects or for emergency response to new invasions. The proportions spent on each strategy should change over time as candidate islands for eradication decline with success and as managers learn how to best intervene to minimise risks of reinvasion. These baseline versus one-off responses usually therefore have different funding streams in government agencies and so might lead to different rankings at least in the timing of any actions required across the candidate islands where rodent management is justified.

There are also factors such as the rodent species present as a measure of risk (ship rats might be considered the worst of the species), the urgency of the threat, the likelihood of recovery of the native species or opportunities for active restoration, feasibility and risks of failure, and social issues that might alter any ranking based entirely on the biodiversity value of the island.

Challenges:

- Not everyone values the same things. Islands given priority for rodent management by an ornithologist might be different from those by a botanist, while Tasmanian mutton-birders might rank their islands quite differently from a threatened species manager. Lord Howe islanders rank their woodhens very highly, but are less concerned about another threatened bird, the currawong. Thus, although there might be legislative reasons to rank rodent management by their impact on threatened species, in practice other island-specific factors may have to be considered if local people or agency priorities are wider than just threatened species.
- This plan focuses prioritisation on the threat to native species from exotic rodents, but an alternative approach might focus the primary prioritisation on the islands as the unit of management regardless of the nature of the threats present. For example, the sequence of eradication of exotic herbivores such as goats or rabbits and of exotic predators such as feral cats on islands with exotic rodents must be considered even if the rodents are the primary target to avoid potential adverse consequences of removing just one trophic level of pests.

3.3 The toolbox

Successful management of exotic rodents also requires an effective, safe, humane, socially acceptable, and affordable set of tools. Many are legally registered for use in Australia but their best-practice application depends on the strategy to be used.

Three baiting methods have proved successful in eradicating rodents on islands:

Aerial sowing of baits is best for large islands or where access on foot is difficult. The baits are sown from commercially available bait-sowing buckets slung under a helicopter. The sowing rates are calibrated to achieve known bait densities and swath widths, and complete bait coverage is ensured by using global positioning systems and by overlapping the sowing swaths. Steep areas are usually covered twice at each sowing. Generally, two distributions of bait, the second at right angles to the first, are applied about 10 days apart at a time of year (usually in winter) when the rodents are not breeding, have least natural food, and when non-target risks (e.g. for nesting seabirds) are minimised. Generally, bait densities are calibrated to ensure many baits are available for each rodent – standard densities have been 8 + 4.5 kg/ha in each sowing.

Smaller islands with easy access on foot can be baited by *hand-broadcasting* the baits following a similar protocol to the above.

The third method has used baits *in covered bait stations* set out in a grid (c. 50 m apart for rats and about 20 m apart for mice). This method also requires access on foot to all areas and requires the stations to be visited and rebaited, as the rodents eat or remove and cache the baits. Thus, the costs to do this limit the scale at which this method is effective. However, bait stations do have the advantage over broadcast baiting in that they change from a control device to a monitoring device that allows any survivors to be detected, located and killed.

Two cereal-based pellet baits have been used with success in aerial and ground-broadcast rodent eradications. Pestoff® 20R, manufactured by Animal Control Products in New Zealand, or Final®, manufactured by Bell Laboratories, USA, both containing brodifacoum, have been used in most recent operations. An effective lethal dose for mice is up to 1.5 g of bait, while for ship rats is up to 50 g of bait. The first signs of anticoagulant poisoning occur a few days after ingestion of a lethal dose so any rodents eating sub-lethal amounts of bait are less likely to associate the bait with symptoms and continue to eat baits they encounter. First-generation anticoagulant toxins have also been used against rats in places where non-target animals cannot be avoided, but these are most effective when rodents eat many consecutively over a number of days, and their efficacy against mice is less well established.

Baits containing waxy substances to increase bait longevity have been used in the bait station methods. The above manufacturers both make such baits, and in addition the Talon® wax baits made by ICI are suitable. Other anticoagulant toxins, such as bromodiolone or diphacinone, are occasionally used. Acute toxins such as compound 1080 or zinc phosphide have not been considered suitable for eradication because it is assumed some rodents would receive sub-lethal doses, associate symptoms with the baits and avoid eating more baits.

For sustained control, rodent populations can evolve traits (e.g. neophobia or resistance to the toxin) or individuals can learn avoidance behaviours (e.g. shyness) that reduce the efficacy of later use of baits, toxins or traps. Best practice is to change between anticoagulants and acute toxins and/or the baits periodically to avoid these aversion behaviours becoming predominant traits in the target population.

Rodenticide baits registered for use in Australia include several wax-block baits containing anticoagulants for use against commensal rodents, and an aerial bait with zinc phosphide for use against mice in agricultural areas. No bait with anticoagulant toxin is currently registered for aerial application. However, baits with anticoagulants may be applied from the air, broadcast by hand, or placed in ground-based bait stations under 'minor use' or 'research use' permits obtained under The Agricultural and Veterinary Code Regulations 1995 (see www.apvma.gov.au). Full registration of an aerially delivered bait for use on islands may be justified if many new eradication attempts are planned. Data gathered during the current operations planned for Macquarie and Lord Howe islands will support such an application by potential bait manufacturers.

Fences have been developed that keep rodents out of areas from which they have been removed. Rodent-proof fences have been mooted as an option for some islands in Australia (e.g. high-priority conservation areas of Norfolk Island).

Best practice for detecting and then dealing with new invasions is evolving with current practice and research. To date, the detection probabilities of various devices and systems of setting them out (e.g. chew cards, wax tags, tracking tunnels, and traps) have not been measured in either validation of eradication or quarantine studies.

Genetic tools now allow managers to answer questions about managing ongoing risks of invasion and reinvasion by rodents on islands. As examples, managers can sometimes identify the source of any rodent found on an island – is it a survivor of an eradication attempt or a new immigrant? (Abdelkrim *et al*. 2007) The genetic diversity of the rodents on an island might be used to infer the numbers of previous colonisation events and so predict future frequencies (Searle *et al*. 2008). In sustained control cases, the identification of discrete sub-populations on the island may identify the scale of control to be optimised (Robertson and Gemmell 2004).

Rodents are not generally highly regarded by people who are used to controlling them as pests. Nevertheless, animal welfare and ethical considerations will play an increasing role in rodent control. Many welfare groups favour eradication over sustained control because fewer individuals are eventually killed under the first option.

3.4 Eradication

Eradication is the permanent removal of the population from the whole island. It requires that all the rodents must be at risk and killed faster than they can replace their losses, that reinvasion risks are zero (or near to it), so that the benefits outweigh the costs of reinvasion (and are manageable), and there should be no net adverse consequences (Hone *et al.* in press).

Modern control tactics (aerial or ground baiting in one operation) ‘over-engineer’ the application of baits, i.e. more baits are applied than strictly needed and they are distributed with overlaps and double sowings to ensure no gaps are left. The baits are best applied outside the rodents’ breeding season, which is usually when natural foods are least abundant, to meet the first rules. This increases the probability that all rodents are placed at risk.

The zero-immigration rule can never logically be met – the rodents got to the island once so theoretically could do so again – but commonsense, ongoing monitoring and perhaps additional research should allow us to judge this risk. Eradication should be considered simultaneously with reinvasion prevention (i.e. surveillance and quarantine). Mitigation of invasive rodent impacts by complete removal must involve both eradication and ongoing reinvasion prevention.

3.5 Sustained control

On islands where eradication is not considered feasible or cost-effective, and there are species urgently requiring protection from invasive rodents, targeted control can provide an ongoing means of species conservation. Targeted rodent control is often used to help species with restricted distributions such as remnant populations or colonial nesting birds (e.g. Providence petrels on Mt Gower on Lord Howe Island, protection of green parrots on Norfolk Island).

With sustained control it is vital to know how to intervene, i.e. how to optimise the scale, frequency and intensity of control sufficient to achieve the protection goals. Too little and the resource might not be protected, and too much wastes effort that could be used elsewhere. Knowledge of both the rodent’s biology and that of the species and ecosystems being protected is usually desirable if such control is to be efficient, and therefore sustainable.

Sustained control is also an important strategy for reducing source populations such as around points of departure for both human-assisted and naturally dispersing rodents.

On islands where reinvasion is certain (i.e. those within easy swimming distance of populations that cannot be eradicated) eradication itself is never achievable, and ongoing surveillance and control will always be required. Quasi-eradication is where the resident population is removed and the potential immigrants are all killed in buffers on the mainland or the actual immigrants are killed as they arrive. The effect on the island’s biodiversity is the same as if eradication was achieved but at an additional ongoing cost.

A version of this strategy is to use rodent-proof fences around areas of high biodiversity value from which the resident rodent populations have been removed. Several fence designs to exclude rats and mice (and other pests) have been built in New Zealand by community conservation groups to protect areas of up to 3400ha. As with islands within swimming distance of mainlands, there are ongoing costs to maintain the fence, detect invading rodents, and then deal with them to maintain the zero-density goal and so optimise the biodiversity benefits. Experience is yet to provide firm data on the extent of these costs compared with alternative strategies of sustained control in the absence of a fence.

3.6 Stopping new invasions

Invasive rodents have been transported by humans to islands, both intentionally and accidentally, since people first started travelling to islands. The rate of ship and Norway rat invasion of rodent-free islands shows no pattern of change over the past century (Russell *et al*. 2008).

Preventing invasions of exotic rodents on rodent-free islands needs to be seen as part of a wider biosecurity plan for each island. Most Australian islands do not have exotic rodents but many will eventually be invaded either naturally or with human assistance via shipwrecks or in cargo landed on the island.

The probability that an exotic rodent species will arrive on an island is determined by whether the island is within swimming distance for the rodent from the mainland (Russell *et al*. 2008), the number, type and port of origin of any vessels visiting, the presence of a wharf (Atkinson 1985) and thus presumably how cargo is unloaded on the island, and the likelihood of ships wrecking on the island. Whether the rodent then establishes and spreads is another matter, but managers usually assume the worst and take a precautionary approach.

Overall, the probability that rodents will invade might be reduced by actions at the point of departure of ships to reduce the chance that rodents will get aboard, by rodent control on ships to reduce the risk that they will disembark on the island, by proactive or prophylactic control around likely points of entry on the islands, and/or by surveillance and reactive management should a rodent be seen on the island. It is not clear which actions give best results given limited resources – although the answer is likely to depend on the pathway of invasion, its likely frequency, and the practicality of conducting effective surveillance and responses.

3.6.1 Control at points of departure

Best practice at ports and airports might include:

- Maintenance of an environment which minimises rodent densities and thus presumably the likelihood of invasive rodents being transported off-site by human-assisted means
- Active control of rodents, and
- Active management of access routes onto vessels. Note: this includes physical inspection of all cargo and luggage being transported to high-priority rodent-free islands in some countries.

3.6.2 Control on ships and planes

There are few data on the distribution of invasive rodents on vessels. Some data from large ships in Alaska suggest it is uncommon to find breeding populations on board, and that rats that embark on a vessel are likely to disembark not long thereafter. Data from smaller scientific/management vessels in New Zealand suggest that rats will commonly move on and off such vessels, especially when rodents are abundant around the port.

International Health Regulations require ships to carry sanitation certificates that incorporate the previous requirements for de-rat certification. This certification is voluntary for vessels visiting some Australian islands when they originate from Australian ports, but a revalidation of the certificate is required for all vessels (over 25 m in length) originating in foreign ports. Less than 0.2% of the 14 200 international vessels inspected by AQIS in 2006/07 had evidence of rodent infestation.

Many of the introductions of black rats to islands off Western Australia came from careened pearling vessels in the late 19th century. Control of rodents (and other pests) on aircraft and shipping servicing the expanding oil and gas industry in Western Australia is now a major issue. Most of the large equipment needed for the construction and operation of this industry is transported to islands by barge, and the exports of oil and gas are by specialised shipping. Helicopters and fixed-wing aircraft are also used extensively to transport people to and from the islands. All increase the chance that exotic rodents may reach the islands, and considerable effort is expended on developing and implementing quarantine measures, and on educating the workers and other island users. In addition, contingency plans are in place, or being developed, for any breaches detected.

3.6.3 Control on an island:

Quarantine measures on an island might be proactive (inspection of cargo, buffers of control devices around likely invasion points) or reactive (surveillance and prompt action when a rodent is detected), or both.

(i) Proactive actions: On islands of particularly high conservation value, i.e. where the presence of a rodent population would certainly lead to the loss of native species, that are also remote and uninhabited, best practice might include a final inspection of all cargo (generally from scientific or conservation expeditions) in 'debriefing rooms' on ship or ashore where all transported cargo that is to be landed is unpacked and inspected. In New Zealand both mice and rats have been intercepted at this point. It is unclear how practical this process would be for populated islands.

Some countries maintain a zone of rodent control around likely invasion points on rodent-free islands. The Pribilof Islands in Alaska have been kept free of exotic rodents, despite hosting hundreds of ships each year, by a buffer of traps and bait stations around the port (Sowls and Byrd 2002). Increasing the bait-life and efficiency of such strategies is the subject of current research in New Zealand.

(ii) Reactive actions: Prompt reaction to shipwrecks on islands is used by some countries. Project Rat-Spill (a spinoff from the Exxon Valdez oil spill in Alaska) ensures that the crews of salvage ships and island residents (as the probable 'first on scene') have equipment and training to react, with on-site rodent control, to any shipwreck.

The final line of defence is planned surveillance or monitoring on rodent-free islands and prompt action against incursions. This might be feasible on populated islands but is likely to be impractical on uninhabited islands that are not regularly visited. The rate of rat population expansion across an island suggests most medium-sized islands (<1000 ha) can be fully invaded by rats in under 2 years. Thus, any surveillance planned needs to be done (assuming perfect detection) at frequent intervals if any invasion is to be intercepted (assuming perfect interception). Otherwise, proactive management to reduce risk is indicated.

Challenges:

- The matrix of the probability of invasion, the cost of detecting and dealing with any invasion, and the consequences for biodiversity values of failure needs to determine how any quarantine system can be optimised. Hard data are generally absent, but managers can broadly consider the simple matrix when the probability is high or low, the costs to detect and remove invaders are high or low, and the consequences of failing to do so before the island is invaded are high or low. What set of responses from control at source, through on-ship hygiene, to surveillance–detection–control action should be applied across this matrix of risk?
- For example, suppose the probability of invasion is high (the island is within swimming distance of a source population), the costs to detect and deal with all rodents that arrive before they invade the whole island are high, but the consequence for biodiversity is low

(at least in the short term). The best response might be to do nothing and just eradicate the pests once an invasion is complete at some convenient time in the future. The alternative, to control the rodents in a buffer in the source population, might logically reduce the probability of invasion – but the evidence to date is not clear.

- But, suppose the probability of invasion is low (a remote oceanic island), the costs to detect and deal with an event are high (no one visits the island very often), but the consequences of a full invasion are high. What should be done? In this case managers must try to lower the invasion probability by good quarantine on visiting vessels and a rapid contingency plan for any catastrophic event such as a shipwreck.

4 Developing national and regional approaches

Each of the broad actions in the response framework (eradication, sustained control and prevention) requires different emphases on how international, national, regional and local governments and stakeholders can best coordinate their actions.

4.1 Coordinating priority actions

The need for periodic funding for eradications or for baseline funding streams for sustained control and ongoing quarantine will determine how government agencies and others participate in rodent management. Strategies that require ongoing resources of money and people (sustained control and quarantine/surveillance) are best done by those closest to the problem – either island residents or local/state agencies – and funded out of ‘normal’ departmental budgets. Development of best-practice tools and guidelines to achieve these strategies may be the area where coordination between national, state and local agencies is most productive.

Eradication and reaction to new invasions do not require an ongoing expenditure, other than for the duration of each project. However, government agencies may need to draw on flexible arrangements to budget for programs with a high between-year variability, for contingency projects such as emergency responses, or for very large projects that may require the involvement of many parties.

Challenge:

- How will this Threat Abatement Plan affect the management of other pests on islands, and vice versa?

4.2 Involving island residents

One role of the Threat Abatement Plan is to begin to identify and encourage the shared responsibilities of governments, island residents, stakeholders and the wider public to own the problem of exotic rodents on islands and support the solutions that will be offered by the active participants. Success in some high-profile islands will build enthusiasm for future work, while support to attempt projects under the plan requires education and outreach.

Many of the islands with exotic rodents and many rodent-free islands are permanently inhabited by people, who are therefore primary stakeholders in this plan. Many island communities have their own local governments that are clearly in the best position to initiate rodent management – and to manage sustained control and quarantine strategies. Fortunately, almost all islanders would be happy to remove rodents or stop them invading their islands, either because the rodents are commensal or economic pests or because the islanders value their native plants and animals.

Nevertheless, islanders may have legitimate concerns, especially about how any rodent control is to be conducted, and early consultation and participation in planning processes is essential.

Indigenous people have considerable interest in islands both as traditional owners under tenures such as Aboriginal lands trusts, or as claimants under native title claims, as well as traditionally and culturally on islands held under other tenures. Many of the islands in the north of Australia are owned or under claim by land trusts. However, only five of these currently have exotic rodents (Table 2.3). However, many important northern islands are held as Aboriginal land trust reserves. In Tasmania six islands with exotic rodents are owned by indigenous people, while in other southern states the only indigenous-owned islands known to have exotic rodents are Wardang and Island Point islands in South Australia.

Many coastal traditional owner claim groups have established natural and coastal resource management projects or ranger groups. These groups recognise the conservation importance of the islands in their area and seek to keep them free of exotic pests. They are thus in a strong position, with appropriate funding support, to deliver services – particularly in the surveillance and quarantine strategies for islands currently without exotic rodents, and in delivering sustained control options on islands with rodents. These management actions would also, of necessity, include the requirement to involve traditional owner groups in ongoing monitoring and research on the islands. Indigenous people as island owners and/or residents can be funded through the Indigenous Protected Areas and other programs.

All this requires early engagement of owners in the development of feasibility and operational plans, and adequate funding through the process to ensure effective participation and employment. Agencies or proponents of management on islands where traditional owners are stakeholders also need to be aware that there are permission requirements for access to such islands. These must be sought through the appropriate channels and usually require that traditional owners are present during any actions on the island.

Challenges:

- Training and resourcing of traditional owners or island residents is required to sustain control of exotic rodents, improve border control and surveillance, for monitoring, and (where appropriate) to assist with eradication.
- Ensuring long-term community support for control programs, and recognition that eradication is an option to be considered as a first response, will be needed.

4.3 Building technical capacity

Most Australian, state and territory conservation and land management agencies have little or no experience in managing exotic rodents on islands, particularly where aerial baiting is essential. None have formal prioritisation plans, although South Australia has ranked its islands for their biodiversity value (Robinson *et al.* 1996), but this has not driven any action against exotic rodents.

Some of the technical experience learnt from the large-scale aerial baiting of mice on mainland Australia can be used, but not replicated, for island eradications. The toxin used, zinc phosphide, is an acute toxin, which may have a role in sustained control strategies on islands but is unlikely to achieve eradication. The techniques cannot be merely copied, because both the mindset and practice of those attempting eradication has to change from one-off control events aimed at immediate mitigation of damage to crops triggered by mouse irruptions; all, rather than most, pests must be killed, and baits, toxins and methods of application must change to do this.

Best practice for aerial eradications has been developed in New Zealand (Broome *et al*. 2005), and the planning and operational details to minimise risks of failure and manage non-target species are available (e.g. McClelland 2002). While the hard-learned processes used by successful eradications around the world can be followed, they cannot be applied as mere recipes in Australia. Western Australia has dominated rodent eradication in Australia, initially using ground-based techniques (e.g. Burbidge and Morris 2002) but later using aerial baiting for ship rats in the Montebello islands. Two large-scale and complex rodent eradications are being planned in Australia – for Lord Howe (New South Wales) and Macquarie (Tasmania) islands.

There is also a need to build technical capacity on islands where sustained control is the strategic option, and for managing risks of invasion. Best-practice methods are not established, and may be very island-specific; suggesting a planned adaptive management approach (or learn-by-doing) could be applied.

4.4 Priorities for filling knowledge gaps

4.4.1 Basic survey information:

The lists of islands with exotic rodents in Table 2.3 show some uncertainties about the species present, and it is likely that some islands not on the list do have rodents.

Any island known to have exotic rodents but of unknown species would require that species to be identified if it were to be considered for management. Islands for which there is no information on the presence or absence of exotic rodents might be added to the list in Table 2.3 after survey. However, there is no system to decide which islands should be surveyed. This should depend on the priority of conservation values potentially at risk on such islands – and no agreed system to assess this exists.

It is often uncertain what non-target native animals are present on islands proposed for rodent management.

4.4.2 Managing invasion risks

It is unclear where along the invasion pathway for exotic rodents (at the source, on ships or planes, or on the island) it is best to intervene to reduce the risk that exotic rodents will invade or reinvade islands. It is also unclear whether it is better to be proactive (set bait stations) or reactive (conduct surveillance and prompt action) on islands free of exotic rodents.

Scenario models should be developed and used to do a risk analysis to direct management, but these models should be revised as monitoring data, on, for example, the frequency of rodent infestation on key vessels, are collected.

Development of effective detection systems for use on rodent-free islands is required. The key information is detection probabilities – the probability that if a rodent is present the detection system will find it.

4.4.3 Sustained control

Sustained control strategies require knowledge of how the pest affects the resources to be protected, so that the frequency and scale of intervention can be planned. The best-practice sequence of control tools (usually various baits and toxins) has not been established, but one could be drafted from overseas experience or from control operation on the mainland of Australia, tested by experience, and updated using sustained control operations proposed for islands in Australia or elsewhere.

4.4.4 Eradication of mice

Eradication of mice, particularly in the presence of rats, appears to be more difficult than eradication of rats (Caut *et al*. in 2007). The causes of this, if true, remain unclear but require either empirical testing (using acceptance trials of non-toxic baits on Lord Howe and Macquarie islands), or more controlled trials designed to test particular hypotheses for the effect.

4.4.5 Non-target issues

Many Australian islands with exotic rodents also have native mammals, birds and reptiles that may be at risk either from primary poisoning where the non-target animal eats the bait, or indirect poisoning as the toxin flows through the food chain. The effect of anticoagulant toxins on reptiles and the role of invertebrates as reservoirs of residual anticoagulants are particular (international) gaps in knowledge.

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Table 2.1: Australian exotic rodent morphological characteristics

	Rattus rattus	*R. norvegicus*	*R. exulans*	*Mus musculus*
Body weight (g)	95–340	200–400	30–100	10–25
Ears	Large, and cover eyes when pulled forward	Do not cover eyes when pulled forward	Smaller than for *R. rattus* but also cover eyes when pulled forward	Smaller than for the rats
Belly fur (characteristic for *R. exulans*)			White-tipped with grey underneath	
Tail	Much longer than head/body length (HBL); uniformly dark	Clearly shorter than HBL; thick with pale underside	About the same as HBL; thin and uniformly dark	About the same as HBL; uniformly grey-brown
Tail length (mm)	185–245	150–215	125–135	75–95
No. of nipples	10–12 (usually 10)	12	8	10

Table 2.2: Status of exotic rodents on Australian islands by jurisdiction (data from Tables 2.3 and 2.4)

Jurisdiction	**No. of islands**	**No. islands <100 000 ha known to now have exotic rodents**	**No. of islands from which rodents have been eradicated**
Commonwealth	37	3[a]	2
Northern Territory	879	2	0
Western Australia	3678	33	33
South Australia	396	18	0
Victoria	246	22	0
New South Wales	439	7	2
Tasmania	804	29	1
Queensland	1854	19	1
Total	8333	133	39
New Zealand	710	145+	92
Galapagos	50	38	4

[a] The 26 islands and atolls in the Southern Cocos/Keeling group are counted as a single island.

Table 2.3 Australian islands known to have one or more species of exotic rodents
1 = ship rat, 2 = Norway rat, 3 = Pacific rat, 4 = mice.
A = Aboriginal trust or freehold, B = national park, C = other conservation reserves, D = non-reserved Crown lands, E = Crown-leased, F = private. Eradication success awaits confirmation on Montague and Muttonbird islands

These lists were compiled from State and Territory lists commissioned by DEW (New South Wales, O'Neill (2005); Northern Territory, Rankmore (2005); Victoria, Johnston (2008); Tasmania, Terauds (2005); South Australia, Anon. (undated); Queensland, Bell *et al*. (2008), and Western Australia, Burbidge (2004). Island areas are those quoted in these reports. Additional data were taken from Abbott and Burbidge (1995), Long (2003) and Robinson *et al.* (1996).

Island	State	Area (ha)	Exotic rodents	Distance to mainland (km)	Tenure	Cat	Rabbit	Fox
Dirk Hartog	WA	58640	4	1.5	E	Y	N	N
Cape Barren	Tas	46220	1, 4	7	A	Y	N	N
Elcho	NT	28244	1	0.6	A	Y	N	N
N. Stradbroke	Qld	26344	1, 4	3.8	C	Y	N	N
French	Vic	17300	4	2400	B, F	Y	Y	Ferrets
Moreton	Qld	17021	4	3500	B	Y	N	N
Bribie	Qld	14346	4	0 (bridge)	B	Y	N	N
Christmas	Com	13470	1, 3?, 4	100 +	B, F	Y	N	N
Macquarie	Tas	12785	1, 4	100+	C	N	Y	N
Burrup (Dampier)	WA	11804	1, 4	0 (causeway)	A	Y	N	N
Maria	Tas	10127	1, 2?, 4	4	B	Y	N	N
Phillip	Vic	10116	1, 4	0 (bridge)	C, F	Y	Y	Y
Three Hummock	Tas	6966	4	3.9	B, E	Y	N	N
Long	Qld	5324	1	0.5	B, F	N	N	N
Faure	WA	5148	4	6.1	C	N	N	N
Snake	Vic	4623	1, 2, 4	0 (at low tide)	B	N	Y?	Y
Flinders	SA	3817	1	28.5	E	Y	N	N
St Peter	SA	3598	4	3.5	C	N	N	N
Norfolk	Com	3450	1, 3, 4	100+	B, F	Y	N	N
Tent	WA	2015	4	0 (at low tide)	C	Y	N	N
St Margaret	Vic	1934	4	0 (at low tide)	F	N	Y?	N
Wardang	SA	1791	4	3.8	A	Y	Y	N
Rottnest	WA	1705	1?, 4	18	C	Y	N	N
Sunday	Vic	1620	1, 4	2.1	C, F	Y	N?	Y
Lord Howe	NSW	1595	1, 4	100+	C, F	N	N	N
Deal	Tas	1576	1	58.8	B	Y?	Y	N
Long	WA	1480	1?	9.3	D	N	N	N
Sunday (Buccaneer)	WA	1330	1, 3	8.1	A	N	N	N
S. Cocos (26)	Com	1310	1, 2?, 4	100+	E	Y	Y	N
Badger	Tas	1243	4	11	A	Y	N	N

Island	State	Area (ha)	Exotic rodents	Distance to mainland (km)	Tenure	Cat	Rabbit	Fox
Prime Seal	Tas	1221	4	6.5	D, E	Y	N	N
Depuch	WA	1121	1	2.5	C	N	N	Y
Garden	WA	1054	4	0 (causeway)	D	Y?	N	N
Wedge	SA	938	4	24.3	C, F	N	N	N
Boston	SA	924	4	5	E	N	N	N
Gidley	WA	845	1	0.2	C	Y	N	N
St Francis	SA	739	1?	3.16	C	Y	N	N
Lindeman	Qld	610	1	1	B, F	N	N	N
Thevenard	WA	589	4	20.8	C, E	N	N	N
Coochiemudlo	Qld	546	4	1	F	Y	N	N
Outer Sister	Tas	545	4	4	C, E	Y	N	N
Dixon	WA	500	4	0.8	D	N	N	N
Little Snake	Vic	486	1, 2, 4	0 (at low tide)	C	N	N	Y
Quail	Vic	480	4	0 (at low tide)	B	Y	N	Y
Dog	Vic	475	1, 4	0 (at low tide)	C	N	N	N
Howick	Qld	446	1	13.5	B	N	N	N
Babel	Tas	440	4	2.6	A	Y	N	N
Reevesby	SA	400	4	12.4	C	N	N	N
Maer (Murray)	Qld	390	3	45 600	A	N	N	N
Dream	Vic	382	4	0 (at low tide)	C	Y	Y	Y
South Molle	Qld	380	1	2.6	B	Y	N	N
Great Dog	Tas	377	1, 4	1.7	A	Y	N	N
Rotamah	Vic	340	1, 4	0.1	B	Y	Y	Y
Erith-Dover	Tas	323	2	1.2	B	N	N	N
E. Scrubby	Vic	323	1	0 (at low tide)	C	N	N	Y
Downes	WA	315	4	0 (at low tide)	D	Y?	N	Y?
Hummock	Vic	313	4	0.9	C	N	N	N
Truant	NT	305	1	21	A	N	N	N
Mt Chappell	Tas	297	1, 4	1.5	A	Y	N	N
Waterhouse	Tas	287	4	3	D, E	Y	N	N
N. Twin Peak	WA	272	1?	8.2	C	N	N	N
Passage	Tas	253	1, 4	1	D, E	N	Y	N
Figure of Eight	WA	248	4	13	C	N	N	N
Swan	Vic	247	1, 2, 4	0 (bridge)	D	Y	Y	Y
Swan	Tas	239	4	3	D, F	Y	Y	N
Hogan	Tas	232	1	39	D	N	N	N
Adele	WA	217	3	69	C	N	N	N
Woody	WA	195	1	5.6	C	N	N	N
Louth	SA	183	4		F	N	Y	N
North (Albrohos)	WA	176	4	18	C	N	N	N
Tin Kettle	Tas	176	1?	0.5	D	N	N	N

Island	State	Area (ha)	Exotic rodents	Distance to mainland (km)	Tenure	Cat	Rabbit	Fox
Forsyth	Tas	167	1?, 4	4	C	N	N	N
Boxer	WA	166	1?	5.3	C	N	N	N
Hunter	Vic	160	1, 2	0 (at low tide)	F	Y	N	Y
East Kangaroo	Tas	157	4	9	C	N	N	N
Clonmel	Vic	140	1, 4	1.5	C	N	Y	N
Great Glennie	Vic	138	1	7.8	C	N	N	N
Big Green	Tas	122	1	2.5	C	N	N	N
Gabo	Vic	126	2, 4	0.5	C	Y	N	N
Trefoil	Tas	117	4	2	A	N	N	N
North West	Qld	106	1, 4	51.9	C	N	N	N
New Year	Tas	98	4?	4.5	C	N	N	N
Eba	SA	92	4	0.7	C	N	N	N
Althorpe	SA	90	1, 4	7.6	C	Y	N	N
Little Green	Tas	86	4	0.8	C, F	N	N	N
Little Dog	Tas	83	1?, 4?	1.2	C, F	Y	N	N
Drum	Vic	79	4	0.3	C	N	Y	N
Carey	WA	78	4	2	C	Y?	N	N
Christmas	Tas	63	4?	0.2	C	N	N	N
Burnside	WA	58	4	0 (at low tide)	C	N	N	Y
Churchill	Vic	57	1, 4	0 (at low tide)	C	N	N	Ferret
Culeenup	WA	51	1, 4	0.1	F	Y	N	Y
Newry	Qld	51	1	0.2	B	N	N	N
Rocky	Qld	38	1	14.1	B	N	N	N
Montague	NSW	36	4	6.8	C	N	Y	N
Boullanger	WA	34	4	1	C	N	N	N
Griffiths	Vic	33	1, 2	0 (causeway)	C	Y	Y	Y
Broughton	NSW	32	1?	2.5	B	Y?	Y	N
Little Broughton	NSW	32	1	0.2	C	N	N	N
High (Caparra)	Qld	29	1	1	D	N	N	N
Granite	SA	26	1, 4	0 (causeway)	C, F	Y	N	Y
Fairfax	Qld	21	1?	70	B	N	N	N
Carnac	WA	19	4.	3.6	C	N	N	N
Baird	SA	18	4	0.7	C	N	N	N
Venus Bay A	SA	18	4	2.1	C	N	N	N
Actaeon	Tas	16	1?	3.1	C	N	Y	N
Boydong	Qld	16	1	19.2	C	N	N	N
Green	Qld	15	1	12.7	B	N	N	N
Jeegarnyeejip	WA	15	1	0.1	F	Y	Y	N
Heron	Qld	14	4	25.7	B	N	N	N
Browse	WA	12	4	147	C	N	N	N
Penguin	WA	12	4	0 (at low tide)	C	N	Y	N

Island	State	Area (ha)	Exotic rodents	Distance to mainland (km)	Tenure	Cat	Rabbit	Fox
Mistaken	WA	10	1	0.1	C	N	Y	N
Lion	NSW	8	1?, 4?	0.5	C	N	N	N
Muttonbird	NSW	8	2, 4	0 (causeway)	C	Y	N	Y
Yunderup	WA	8	4	0.1	F	N	Y	N
Southport	Tas	7	4	0.4	D	N	Y	N
Whitlock	WA	7	4	1.4	C	N	N	N
Meeyip	WA	7	4	0.1	F	N	Y	Y
North Bickers	SA	7	4	1.4	B	N	N	N
Goose	SA	6	4	0.5	C	N	N	N
Three Bays	WA	5	4	1.1	C	N	N	N
S. Bickers	SA	4	4	1.4	B	N	N	N
Wreck	Qld	4	1?	12.6	B	N	N	N
Little Goose	Tas	4	4	0.3	C	N	N	N
Little Boydong	Qld	3	1?	21	C	N	N	N
Island Point	SA	3	4	0 (at low tide)	A	N	N	N
Doughboy	Vic	2	1	3.8	B	N	N	N
George Rocks	Tas	2	1	2.8	C	N	Y	N
Little Goose	SA	2	4	0.3	C	N	N	N
Snapper	NSW	1	2	0.1	C	N	N	N
Sugar Loaf	WA	1	4	0.1	C	N	N	N
Merri	Vic	1	1	0.05 (50 mtrs)	C	N	N	Y

Table 2.4: Australian islands from which rodents have been eradicated
A = Aboriginal trust or freehold, B = national park, C = other conservation reserves, D = non-reserved Crown lands, E = Crown-leased, F = private

Island	Area (ha)	State	Species	Management agency	Tenure
Barrow	Part of 22 483	WA	Ship rat, mice	Conservation Commission	C
Hermite	1 022	WA	Ship rat	Conservation Commission	C
Trimouille	522	WA	Ship rat	Conservation Commission	C
Middle (Barrow)	350	WA	Ship rat	Conservation Commission	C, E
Boodie	170	WA	Ship rat	Conservation Commission	C, E
North West	135	WA	Ship rat	Conservation Commission	C
Alpha	118	WA	Ship rat	Conservation Commission	C
Varanus	83	WA	Mice	Conservation Commission	C, E
West (Lacepede)	82	WA	Ship rat	Conservation Commission	C
Bluebell	65	WA	Ship rat	Conservation Commission	C
Middle (Lacepede)	60	WA	Ship rat	Conservation Commission	C
Renewal	58	WA	Ship rat	Conservation Commission	C
Rat	56	WA	Ship rat	Minister for Fisheries	C
Bowen	51	NSW	Ship rat	Dept. Environment & Conservation	B
Campbell	47	WA	Ship rat	Conservation Commission	C
Crocus	41	WA	Ship rat	Conservation Commission	C
Primrose	41	WA	Ship rat	Conservation Commission	C
Delta	38	WA	Ship rat	Conservation Commission	C
Brush	36	NSW	Ship rat	Dept. Environment & Conservation	C
Bedout	30	WA	Ship rat	Conservation Commission	C
Bridled	27	WA	Mice	Conservation Commission	C
S. Double	23	WA	Ship rat	Conservation Commission	C
Ah Chong	22	WA	Ship rat	Conservation Commission	C
Brooke	15	WA	Ship rat	Conservation Commission	C
Heron	13	Qld	? Ship rat	National Park	B
W. Coringa Cay	13	Com	Ship rat		
South east	13	WA	Ship rat	Conservation Commission	C
N. Double	12	WA	Ship rat	Conservation Commission	C
Shelter	8	WA	Ship rat	Conservation Commission	C
Sandy	6	WA	Ship rat	Conservation Commission	C
Boomerang	5	WA	Ship rat	Conservation Commission	C
West Ashmore	5	Com	? Ship rat		
Ivy	4	WA	Ship rat	Conservation Commission	C
Prince	4	WA	Ship rat	Conservation Commission	C
Bloodwood	3	WA	Ship rat	Conservation Commission	C
Pigeon	3	WA	Ship rat	Minister for Fisheries	C
Pasco	2	WA	Ship rat		C

Fisher	1	Tas	Ship rat		
Beacon	1	WA	Mice		

Table 2.5: Rodent species and combinations on Australian islands of <100 000 ha

Species combinations	No. islands	Largest island eradicated in Australia
Mice only	59	Varanus, 83 ha
Ship rat only	36	Hermite, 1022 ha
Pacific rat only	2	
Norway rat only	2	
Ship rat and mice[a]	22	Barrow but only in separate parts of island (around the camps for mice and over c. 270 ha for the rats)
Ship rat and Norway rat	2	
Ship rat and Pacific rat	1	
Ship rat, Pacific rat and mice	2	
Ship rat, Norway rat and mice	5	
Norway rat and mice	2	

[a] All 26 Southern Cocos islands and atolls counted as one island.

Table 2.6: Eradications of rodents from islands worldwide
All these largest successes were achieved using brodifacoum baits sown from the air.

Species	No. successful eradications	No failed eradications	Largest island with successful eradication
Ship rat	160	15	Hermite (Australia), 1022 ha
Norway rat	104	5	Campbell (NZ), 11 300 ha
Pacific rat	55	6	Hauturu (NZ), 3083 ha
Mice	30	7	Enderby (NZ), 710 ha

Table 2.7: Species that became extinct on Australian islands
Diagnosing the cause of extinction is not always simple as some extinctions may be driven by several agents either simultaneously or sequentially. The diagnoses noted here and in **Table 2.8** are taken from the sources summarised in Garnett and Crowley (2000) and from the EPBC Act lists.

Species	**Island**	**Year last recorded**	**Probable threats**
Grey-headed blackbird (*Turdus poliocephalus poliocephalus*)	Norfolk	1975	Ship rats
Kaka (*Nestor productus*)	Norfolk	1851	Habitat changes, Pacific rat?
Long-tailed triller (*Lalage l. leucophaga*)	Norfolk	1940s	Ship rat, habitat changes
Pigeon (*Hemiphaga novaeseelandiae spadicea*)	Norfolk	1900	Hunting, Pacific rat?
Tasman starling (*Aplonis fusca fusca*)	Norfolk	1923	Competition, Pacific rat?
White-chested white eye (*Zosterops albogularis*)	Norfolk		Ship rat
Gerygone (*Gerygone insularis*)	Lord Howe	1936	Ship rat
Grey fantail (*Rhipidura fuliginosa cervina*)	Lord Howe	1924	Ship rat
Robust white eye (*Zosterops strenuous*)	Lord Howe	1918	Ship rat
Tasman starling (*Aplonis fusca hulliana*)	Lord Howe	1918	Ship rat
Vinous-tinted thrush (*Turdus poliocephalus vinitinctus*)	Lord Howe	1913	Unclear
Long-eared bat (*Nyctophilus howensis*)	Lord Howe		Ship rat
Land snail (*Epiglypta howinsulae*)	Lord Howe		Ship rat
Land snails (*Placostylus bivaricosus etheridgi and cuniculinsulae*)	Lord Howe		Ship rat
Weevil (*Hybomorphus melanosomus*)	Lord Howe		Mice
Bulldog rat (*Rattus nativitatis*)	Christmas		Ship rat
Maclear's rat (*Rattus macleari*)	Christmas		Ship rat
Rail (*Gallirallus phillipensis macquariensis*)	Macquarie	1894	Ship rat (in part)
Red-crowned parakeet (*Cyanoramphus novaezelandiae erythrotis*)	Macquarie		Ship rat (in part)

Table 2.8: Species listed as threatened that have been extirpated from any Australian islands where exotic rodents are thought to be a significant cause of the loss

Species	Island	Year last recorded	Probable threats
Kermadec petrel (*Pterodroma n. neglecta*)	Lord Howe	After 1918	Ship rats
Phasmid (*Dryococelus australis*)	Lord Howe	After 1918	Mice, ship rats
Providence petrel (*Pterodroma solandri*)	Norfolk		Hunting, Pacific rats?
Pycroft's petrel (*Pterodroma pycrofti*)	Norfolk	c. 1800	Pacific rats, hunting
Blue petrel (*Halobaena caerulea*)	Macquarie	Only on stacks	Ship rats, other predators
Buff-banded rail (*Gallirallus philippensis andrewsi*)	S. Cocos	1980s	Ship rats, cats
Burrowing bettong (*Bettongia lesueur*)	Boodie		Ship rats

Appendix A Extracts from the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) relating to the requirements for developing threat abatement plans.

Section 271 Content of threat abatement plans

(1) A threat abatement plan must provide for the research, management and other actions necessary to reduce the key threatening process concerned to an acceptable level in order to maximise the chances of the long-term survival in nature of native species and ecological communities affected by the process.

(2) In particular, a threat abatement plan must:
- (a) state the objectives to be achieved; and
- (b) state criteria against which achievement of the objectives is to be measured; and
- (c) specify the actions needed to achieve the objectives; and
- (g) meet prescribed criteria (if any) and contain provisions of a prescribed kind (if any).

(3) In making a threat abatement plan, regard must be had to:
- (a) the objects of this Act; and
- (b) the most efficient and effective use of the resources that are allocated for the conservation of species and ecological communities; and
- (c) minimising any significant adverse social and economic impacts consistently with the principles of ecologically sustainable development; and
- (d) meeting Australia's obligations under international agreements between Australia and one or more countries relevant to the species or ecological community threatened by the key threatening process that is the subject of the plan; and
- (e) the role and interests of indigenous people in the conservation of Australia's biodiversity.

(4) A threat abatement plan may:
- (a) state the estimated duration and cost of the threat abatement process; and
- (b) identify organisations or persons who will be involved in evaluating the performance of the threat abatement plan; and
- (c) specify any major ecological matters (other than the species or communities threatened by the key threatening process that is the subject of the plan) that will be affected by the plan's implementation.

(5) Subsection (4) does not limit the matters that a threat abatement plan may include.

Section 274 Scientific Committee to advise on plans

(1) The Minister must obtain and consider the advice of the Scientific Committee on:
- (a) the content of recovery and threat abatement plans; and
- (b) the times within which, and the order in which, such plans should be made.

(2) In giving advice about a recovery plan, the Scientific Committee must take into account the following matters:
- (a) the degree of threat to the survival in nature of the species or ecological community in question;
- (b) the potential for the species or community to recover;
- (c) the genetic distinctiveness of the species or community;
- (d) the importance of the species or community to the ecosystem;

(e) the value to humanity of the species or community;

(f) the efficient and effective use of the resources allocated to the conservation of species and ecological communities.

(3) In giving advice about a threat abatement plan, the Scientific Committee must take into account the following matters:

(a) the degree of threat that the key threatening process in question poses to the survival in nature of species and ecological communities;

(b) the potential of species and ecological communities so threatened to recover;

(c) the efficient and effective use of the resources allocated to the conservation of species and ecological communities.

Section 279 Variation of plans by the Minister

(1) The Minister may, at any time, review a recovery plan or threat abatement plan that has been made or adopted under this Subdivision and consider whether a variation of it is necessary.

(2) Each plan must be reviewed by the Minister at intervals of not longer than 5 years.

(3) If the Minister considers that a variation of a plan is necessary, the Minister may, subject to subsections (4), (5), (6) and (7), vary the plan.

(4) The Minister must not vary a plan, unless the plan, as so varied, continues to meet the requirements of section 270 or 271, as the case requires.

(5) Before varying a plan, the Minister must obtain and consider advice from the Scientific Committee on the content of the variation.

(6) If the Minister has made a plan jointly with, or adopted a plan that has been made by, a State or self-governing Territory, or an agency of a State or self-governing Territory, the Minister must seek the co-operation of that State or Territory, or that agency, with a view to varying the plan.

(7) Sections 275, 276 and 278 apply to the variation of a plan in the same way that those sections apply to the making of a recovery plan or threat abatement plan.

Environment Protection and Biodiversity Conservation Regulations 2000

Reg 7.12 Content of threat abatement plans

For paragraph 271 (2) (g) of the Act, a threat abatement plan must state:

(a) any of the following that may be adversely affected by the key threatening process concerned:

(i) listed threatened species or listed threatened ecological communities;

(ii) areas of habitat listed in the register of critical habitat kept under section 207A of the Act;

(iii) any other native species or ecological community that is likely to become threatened if the process continues; and

(b) in what areas the actions specified in the plan most need to be taken for threat abatement.