

Introduced mammal eradications for nature conservation on Western Australian islands: a review

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Abstract There are about 3400 islands off the Western Australian coast, many of which have high nature conservation values. Eleven species of introduced mammals occur or occurred on 124 islands, including three domestic animals (horse, camel and sheep) that have not become feral. In addition, Aborigines introduced dingoes to at least four islands before European settlement. Six exotic mammals (red fox, feral cat, goat, rabbit, black rat and house mouse) have now been eradicated from more than 45 islands in a series of projects since the 1960s. Most effort has been directed at black rats with more than 31 islands now clear of this species. Pindone, vacuum-impregnated into oats, was used until the 1990s, when bran pellets with brodifacoum were used in the Montebello Islands. Rabbits have been eradicated using carrots soaked in sodium monofluoroacetate (1080), red foxes with dried meat baits impregnated with 1080 and cats with a combination of baiting and trapping. After a period of 20 years of ground shooting, goats were finally eradicated from Bernier Island using an experienced shooter operating from a helicopter. The house mouse has been eradicated from Barrow Island four times after introductions in food and equipment, and from Varanus and adjacent islands after introduction in food containers. Both islands are utilised by the petroleum industry. Difficulties and how they were overcome, and future eradication priorities, are discussed.

Keywords Exotic mammal eradications; rabbit; *Oryctolagus cuniculus*; goat; *Capra hircus*; house mouse; *Mus domesticus*; black rat; *Rattus rattus*; red fox; *Vulpes vulpes*; feral cat; *Felis catus*; sodium monofluoroacetate (1080); brodifacoum.

INTRODUCTION

Western Australia (WA) covers about one-third of Australia and has a correspondingly long coastline of about 12,500 km (Fig. 1). Most stretches of the coast are abundantly provided with offshore islands, islets and rocks, with only three long stretches of coast being island-free – the Great Australian Bight where the Nullarbor Plain meets the Southern Ocean, an area on the west coast adjacent to the Zuytdorp Cliffs between Kalbarri and Shark Bay and the Eighty Mile Beach between Cape Keraudren and Broome. If an island is defined as any feature above high water mark shown on a 1:100,000 map, there are 3424 islands in all (Department of Land Administration data, see Burbidge 1989). Most of these ‘islands’ are small with only 254 islands being larger than 100 ha; 90% of these are in tropical seas (Abbott 2000).

Most WA islands have very high nature conservation values (Burbidge 1989). These values include:

- the persistence of species of mammals now extinct or threatened on mainland Australia (Burbidge *et al.* 1997; Burbidge 1999);
- the presence of endemic taxa of mammals (Burbidge 1999), birds (Schodde and Mason 1999; Garnett and Crowley 2000) and reptiles (Cogger *et al.* 1993), many of which are listed as threatened, and of genetically unique populations of mainland species;
- the existence of examples of mainland ecosystems isolated by rising sea levels 14,000 to 6000 years ago that have evolved in isolation and that have not been affected by the exotics now widespread on mainland Australia;

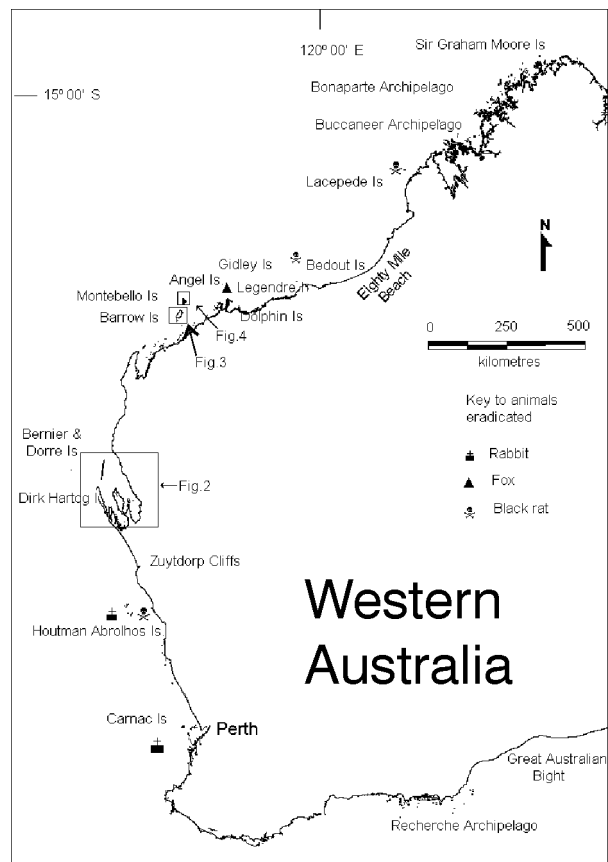


Fig. 1 Western Australian coastline showing islands where eradications have been undertaken. Detail of some islands provided in Figs. 2 to 4.

Table 1 Introduced mammals and eradications on Western Australian islands

Feral mammal	Number of islands recorded	Number of islands eradicated	Number naturally extinct (or domestics removed)
Black rat*	40	31	-
Polynesian rat	2	-	-
House mouse	21	4	-
Dingo	4	-	-
Fox	8	4	-
Feral cat	17	2	5
Rabbit	14	6	2
Horse	2	-	2
Pig	1	-	-
Camel	1	-	1
Goat	6	1	1
Sheep	8	-	6
TOTAL	124	48	17

* Black rat also occurred on and was eradicated from 30-50 small islands (<15 ha) in the Montebello Islands.

- breeding sites for about 30 species of seabirds – in April 2001 the Department of Conservation and Land Management (CALM) Seabird Breeding Islands Database (Burbidge and Fuller 1996) contained 4821 breeding records of 42 species of ‘seabirds’ (as well as true seabirds the database includes other birds that breed on islands and depend on the ocean for their living) on 553 islands, and:
- nesting rookeries of four species of marine turtles (green turtle (*Chelonia mydas*), flatback turtle (*Natator depressus*), loggerhead turtle (*Caretta caretta*) and hawksbill turtle (*Eretmochelys imbricata*)) – most WA rookeries are on islands and many rookeries on the mainland are threatened by predation of eggs by the red fox (*Vulpes vulpes*) (Environment Australia 1998).

RESULTS

Islands with mammals

The Mammals on Australian Islands Database (Abbott and Burbidge 1995) demonstrates that at least 124 WA islands have or had introductions of 11 species of exotic mammals (Table 1). Most records are of black (ship) rats (*Rattus rattus*) (>40 islands), followed by the house mouse (*Mus domesticus*) (21), and feral cat (*Felis catus*) (17). Other recorded introductions are of Polynesian rat (*Rattus exulans*), red fox, European rabbit (*Oryctolagus cuniculus*), horse (*Equus caballus*), pig (*Sus scrofa*), one-humped camel (*Camelus dromedarius*), goat (*Capra hircus*), and sheep (*Ovis aries*).

In addition, dingoes (*Canis lupus dingo*) have been recorded on four islands (Augustus, Bigge, Middle Osborne

and Wollaston) off the Kimberley coast. Dingoes were introduced to Australia about 3500 to 4000 years BP (Corbett 1995), well after island separation; therefore Aborigines, who in this part of Australia possessed limited seagoing capacity, presumably introduced dingoes to these islands.

Most islands off the WA coast south of the Kimberley have been reserved for nature conservation and are vested in the Conservation Commission of Western Australia and managed by the WA Department of Conservation and Land Management. The detrimental effects of exotic mammals on nature conservation values of islands are well documented (e.g., Atkinson 1985; Burbidge 1989, 1999, Burbidge *et al.* 1997) and the eradication of exotics from islands is an important Departmental role.

Case Studies

The eradication of exotic mammals for nature conservation purposes on WA islands commenced in the 1960s with a failed attempt to eradicate rabbits on Carnac Island near Perth using sodium monofluoroacetate (‘1080’) in oats. The first successful eradication was on the same island when, in May 1969, rabbits were eradicated using 1080 in fresh carrots (Morris 1989). Morris (1989) reported eradications from 1968 to 1985. All WA island eradications are summarised in Table 2 and eradication methods are summarised in Table 3.

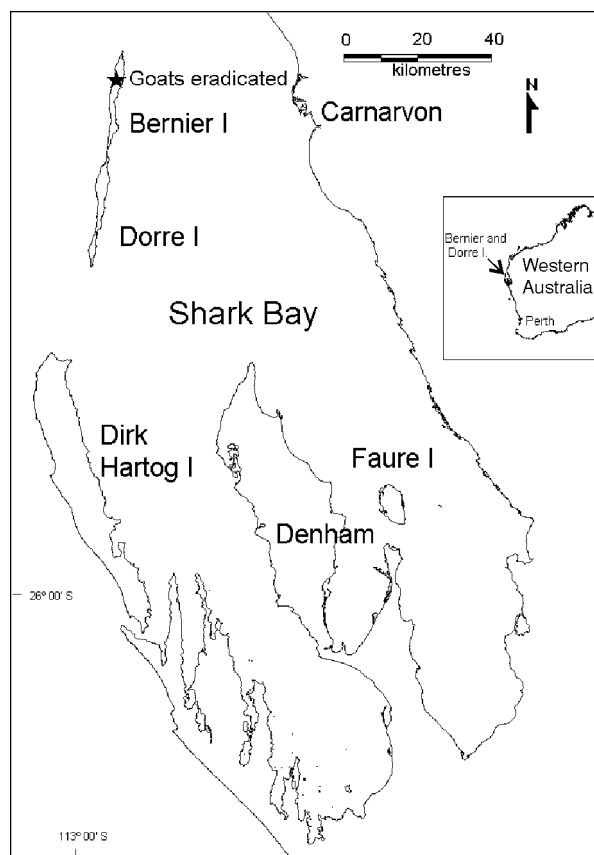


Fig. 2 Shark Bay area, showing Bernier, Dorre and Dirk Hartog Islands.

Table 2 Successful exotic mammal eradications on Western Australian islands 1969 to 2000

Island	Area (ha)	Year	Conservation values protected	Reference
Rabbit (<i>Oryctolagus cuniculus</i>)				
Carnac	19	1969	Breeding seabirds, vegetation	Morris 1989
Wooded	14		Breeding seabirds, vegetation	Morris 1989
Morley	7		Breeding seabirds, vegetation	Morris 1989
Leo	21		Breeding seabirds, vegetation	Morris 1989
Green Islets	6		Breeding seabirds, vegetation	Morris 1989
Goat (<i>Capra hircus</i>)				
Bernier	4267	1984	Threatened mammals, vegetation	Morris 1989
Black rat (<i>Rattus rattus</i>)				
Bedout	24	1981	Breeding seabirds	Morris 1989
Prince	4	1983	Adjacent to Barrow I	Morris 1989
Double	12 + 23	1983	Breeding seabirds, adjacent to Barrow I	Morris 1989
Boomerang	5	1985	Adjacent to Barrow I	Morris 1989
Pasco	2	1985	Adjacent to Barrow I	Morris 1989
Boodie	170	1985	Threatened mammal, adjacent to Barrow I	Morris 1989
West, Middle and Sandy, Lacepede Islands	82, 42, 6	1986	Breeding seabirds, turtle rookeries	R.I.T. Prince, pers. comm.
Barrow*	23 000*	1990/91	Threatened mammals	Morris (2002)
Middle (near Barrow)	350	1991	Threatened mammal, adjacent to Barrow I	Morris (2002)
Rat and adjacent islands (Houtman Abrolhos)	56	1993	None on island, possible invasion of nearby seabird breeding islands	Burbidge <i>et al.</i> unpublished
Montebello Islands (c. 180 islands, islets and rocks)†. Largest island (520 ha) to be used for mammal re-introduction/introduction	total >2000	1996, 1999	Breeding seabirds, turtle rookeries, islands	Burbidge 1997
House mouse (<i>Mus domesticus</i>)				
Barrow‡	23 000‡	1965, 1972, 1994, 1998	Threatened mammals, many other values	Butler 1970, 1985 CALM records
Varanus, Bridled, Beacon (Lowendal Islands)	80 + 22 + 1.2	1994-97	Breeding seabirds, vegetation	I. Stejskal, and J. Angus, pers. comm.
Red fox (<i>Vulpes vulpes</i>)				
Dolphin	3281	1980-1985	Native mammals	CALM records
Angel	927	1980	nature reserve	CALM records
Gidley	798	1980	nature reserve	CALM records
Legendre	1286	1980	adjacent to nature reserve	CALM records
Feral cat (<i>Felis catus</i>)				
Hermite (Montebello Islands)	1020	1999	Will allow reconstruction of vertebrate fauna	Algar <i>et al.</i> (2002)

* Eradication necessary over only 270 ha

† Eradication achieved on all but the largest island (Hermite 1020 ha)

‡ Introduced in food or equipment, eradicated before establishment

WA eradication operations present examples of the difficulties that arise and the ways that these are solved. Some examples are:

- Goats on Bernier Island. Goats were introduced to Bernier Island (4267 ha; Fig. 2) in 1899, when it was a pastoral lease. Initial attempts to eradicate goats during 1962-1972 involved shooters on the ground. Over 550 goats were removed during this period, but by the mid-1970s it became clear that the technique would never succeed as some goats could escape shooters by hiding in vegetation or in caves in cliffs. In 1984 fund-

ing became available to conduct helicopter shooting, utilising an experienced pilot-shooter team who had been involved in donkey control on the mainland. This proved a successful strategy (Morris 1989).

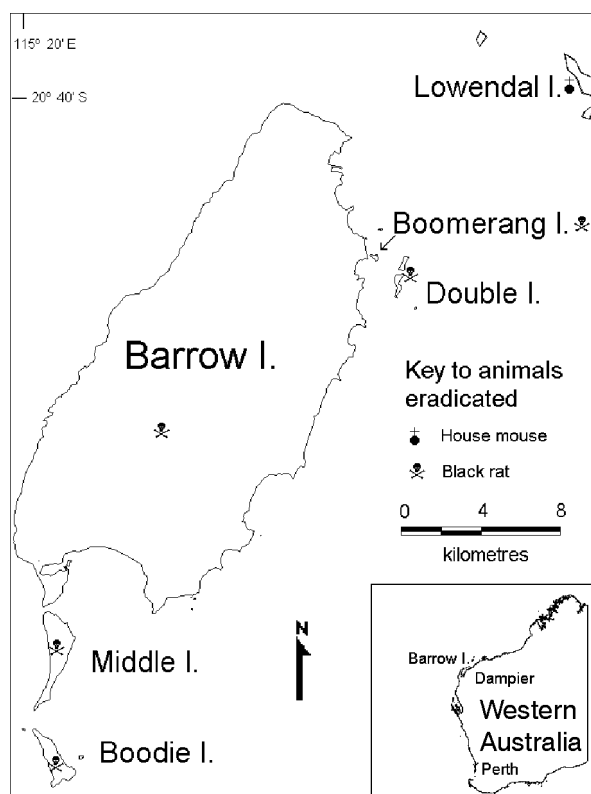
- Black rats on Barrow and Middle Islands (Fig. 3). Barrow Island (c. 23,000 ha) harbours many species of native mammals, including several that are listed as threatened, while the adjacent Middle Island (Fig. 3) has the threatened golden bandicoot (*Isodon auratus*). Eradication required the development of a suitable bait station that excluded native species (Morris 2002).

Table 3 Eradication methods

Rabbit:	1080 in fresh carrots, three days of pre-baiting
Black rat:	Prior to 1996: Oats vacuum-impregnated with pindone on 25 m grid Post-1996: bran pellets with brodifacoum on 50 m grid, bran pellets with brodifacoum laid by helicopter
House mouse:	Varanus and adjacent islands: pindone-impregnated wheat and wax blocks with brodifacoum laid in bait stations on 20 m grid Barrow: bran pellets with brodifacoum
Red fox:	1080 in dried meat baits
Feral cat:	1080 in feral cat 'sausage' baits, followed by leg hold trapping
Goat:	Helicopter shooting

■ Foxes on islands in the Dampier Archipelago. Red foxes self-introduced to Dolphin (3281 ha), Angel (927 ha), Gidley (798 ha) and Legendre (1286 ha; Fig. 1) sometime between 1930 and 1950 (Morris 1989). On Dolphin a population of Rothschild's rock-wallaby (*Petrogale rothschildi*) was near extinction by the 1970s, but remained abundant on nearby Enderby and Rosemary Islands, which did not have any foxes. Dolphin also has a population of the marsupial carnivore the northern quoll (*Dasyurus hallucatus*). In 1980, the use of dried meat baits with 1080 allowed the eradication of foxes without affecting the native carnivore, which has a significantly higher LD₅₀ (6.0-7.5 mg/kg cf. 0.13 mg/kg), even though the indigenous species has a lower body weight (fox c. 6 kg; quoll c. 250 g) (King *et al.* 1989). As well, dried meat baits are not attractive to the quoll. Re-invasion of foxes to Dolphin Island occurred in 1985 necessitating re-baiting. Since then Dolphin has been baited annually and the adjacent Burrup Peninsula has been baited four times per year. Monitoring of Dolphin has continued. The rock-wallaby population has recovered.

■ House mouse on Varanus Island (Lowendal Islands; Fig. 3). In May 1993, the house mouse was introduced to Varanus Island (80 ha) in food containers supplied to an oil and gas base operated by Apache Energy. From there it spread naturally to nearby Bridled (22 ha) and Beacon (1.2 ha) Islands. Initial attempts by the company to eradicate near their facilities and then across all of Varanus Island using wheat with 1080 failed, probably due to insufficient bait being laid in bait stations that were too far apart and lack of follow up. After consultation with experts and better planning, eradication was achieved using wheat vacuum-impregnated with Pindone and wax blocks with brodifacoum laid in bait stations on a 20 m grid and maintained over a period of months. Eradication was achieved in 1997 (I. Stejskal, Apache Energy and John Angus, CALM, pers. comm.)

**Fig. 3 Barrow, Middle, Boodie and the Lowendal Islands.**

■ Rats on the Montebello Islands. Black rats were introduced to the Montebellos (an archipelago of about 180 islands, islets and rocks totalling >2000 ha; Fig. 4) in the second half of the 19th century (Burbidge *et al.* 2000). The presence of two granivorous birds (bar-shouldered dove *Geopelia humeralis* and brown quail *Coturnix ypsilophora*) required the development of a bait station that excluded these species and allowed access by rats. Experimentation on one island in 1995 showed that a bait station comprising a plastic bottle with two 43 mm holes cut in its sides provided a suitable method and in 1996 over 12,000 bait stations were installed and serviced on a 50 m grid on all islands. Eradication was achieved on all islands except the largest, Hermite at 1020 ha and two adjacent smaller islands, where rats were not detected until 1999 (Burbidge *et al.* 2000). No effects on the granivorous birds or on any other species, including raptors, were detected. A further eradication attempt, utilising bait laid from a helicopter spreader bucket, will take place.

DISCUSSION

The above operations provide a useful background to a discussion of eradication technology and issues.

Eradication, as opposed to control, is the desirable and possible outcome of operations against exotic mammals on islands. Parkes (1990, 1993), Bomford and O'Brien (1995) and Myers *et al.* (2000) have discussed eradica-

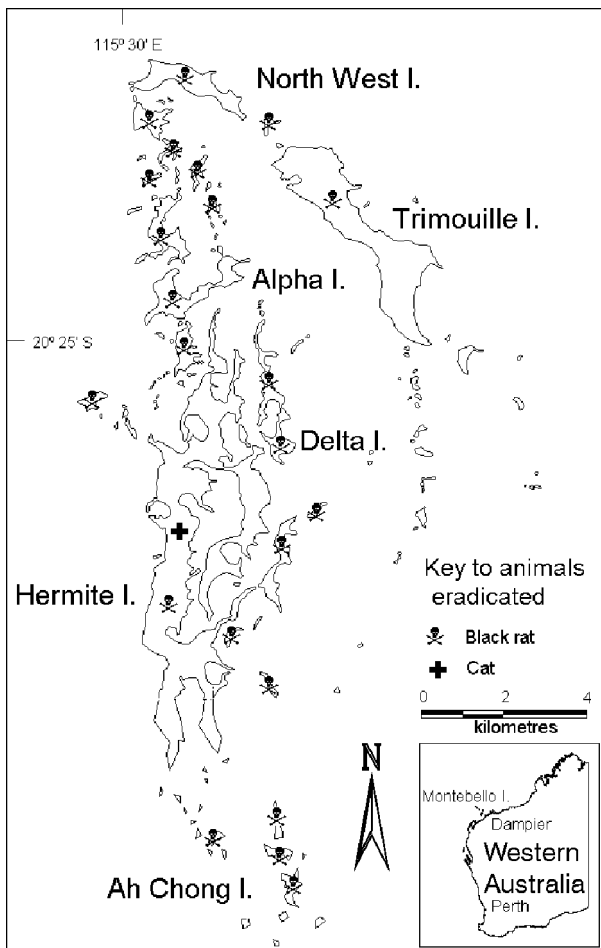


Fig. 4 Montebello Islands.

tion design and practice. Eradication on islands can be achieved if:

- the method used is capable of affecting all of the target animals over a short time,
- the method used kills or captures animals the first time they come into contact with the control method, so that bait or trap shyness does not occur,
- those carrying out the eradication have planned the operation to overcome all foreseeable obstacles,
- the method is applied until eradication is achieved, even if problems arise – financial planning needs to take account of possible initial failures and funding must be committed for the period needed,
- post-operational monitoring is carried out over an appropriate period of time, and
- programmes are in place to minimise the chance of re-invasion.

All the above are equally important. If a well-planned and implemented project fails a change in tactics may be needed – there is little point in repeating the same technique.

In addition, operations on islands with nature conservation values must take place with zero or acceptable impact on those values. Thus, the method used must be specific to the target species. Most operations on islands involve the use of poison in bait that is attractive to the target spe-

cies. If there are no at-risk, non-target species present the technique can be used freely. If there are at-risk non-targets, the poison must either have no significant impact on them, or be presented in a way that makes it unavailable to them. In the latter case, experimentation may be required to develop bait stations that prevent access by non-targets. In some cases, where a very high conservation value species or community is being protected, some negative impacts may be acceptable if other alternatives are unacceptable. A further method, with limited application, is to remove the non-target animals, maintain them in captivity and return them after the bait is no longer effective. Where the possible effect of a technique is unknown, to where an established technique is proposed for use in a new environment, a pilot project/study may be required to ensure that non-targets are not significantly affected. That this can be the case is when brodifacoum was used in the Queen Charlotte Islands, Canada (Howald *et al.* 1999).

Various eradication operations in WA demonstrate the wide variety of problems presented and the ways that they can be overcome.

- The Bernier Island goat operation initially used a technique that was not capable of affecting all target animals in a short time – natural reproduction eventually equalled or became greater than the rate of population

Table 4 Future island eradication challenges for Western Australia

Red fox:	Depuch (1120 ha)
Feral cat:	Faure Island (5000 ha), Dirk Hartog Island (60,000 ha), Cocos-Keeling Islands (Home Island 100 ha, West Island 660 ha, South Island 390 ha)
Black rat:	Completion of Montebello Islands eradication, rats remain on Hermite 1020 ha, 140 km coastline)
Polynesian rat:	Eradication on two islands from which it is known, survey of other Kimberley islands
Pig:	Sir Graham Moore Island (2770 ha)

Table 5 Largest islands where eradication achieved for six feral mammals

Feral mammal	Largest Island.
Rabbit	Leo (Houtman Abrolhos) (21 ha)
Black rat	Trimouille (Montebellos) (520 ha) #
House mouse	Varanus (Lowendal Islands) (80 ha)
Fox	Dolphin (Dampier Arch.) (3280 ha)
Cat	Hermite (Montebellos) (1020 ha)
Goat	Bernier (4267 ha)

Eradication necessary over only 270 ha of 23,000 ha Barrow Island

reduction. Only when a better technique – helicopter shooting – became available, was eradication achieved.

- The Dampier Archipelago fox eradication shows that careful bait formulation can lead to eradication in the presence of a native mammal with a similar diet. It also shows that monitoring of re-invasion is needed, especially where the exotic remains nearby, and that a control or eradication operation may also be needed on nearby land.
- The Barrow Island/Middle Island rat eradication provides an example where the development of an appropriate bait station ensured that non-target mammals were not affected by eradication projects.
- The Varanus Island mouse operation provides an example where initial attempts to eradicate were poorly conceived, but where better design and a long-term commitment did result in eradication.
- The Montebello Islands rat operation is an example of the need to monitor post-baiting and to persist until eradication is achieved, despite a significant financial cost.

FUTURE NEEDS

Exotic mammals remain on several Western Australian offshore islands of nature conservation significance and further eradication operations will be needed. Table 4 shows some of the challenges that lie ahead. With the recent eradication of cats on Hermite Island (Algar *et al.* 2002), the technology to eradicate the exotic mammals concerned is available and tested in Western Australia for all exotic species except the pigs on Sir Graham Moore Island. However, some of the islands are significantly larger than the largest where eradication has so far been achieved (Table 5). In particular the eradication of goats and feral cats from the 60,000 ha Dirk Hartog Island will be a significant challenge.

WA islands are increasingly being used by the petroleum and aquaculture industries and for recreation. Quarantine procedures developed for Barrow Island by West Australian Petroleum Pty Ltd (now incorporated into Chevron Australia) have demonstrated that quarantine can be successful (Butler 1989). However, it has failed on at least four occasions when house mice have entered the island via food containers or in equipment. Even with the best will and efforts, quarantine can never be 100% successful and use of islands with high nature conservation values by industry should be minimised.

With boat ownership rapidly increasing, visits to islands for recreational purposes by Western Australians are also increasing. Monitoring of islands by conservation agency staff and others is needed to maximise the chance of detecting introductions as early as possible and response

manuals are needed to allow staff to take appropriate and timely action.

CONCLUSIONS

Eradication of exotic mammals on WA islands of nature conservation significance has been achieved through a series of successful operations. Eradications are still required on several islands and steps are needed to prevent introductions continuing. There is an urgent need to develop monitoring protocols and a response manual for WA islands.

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