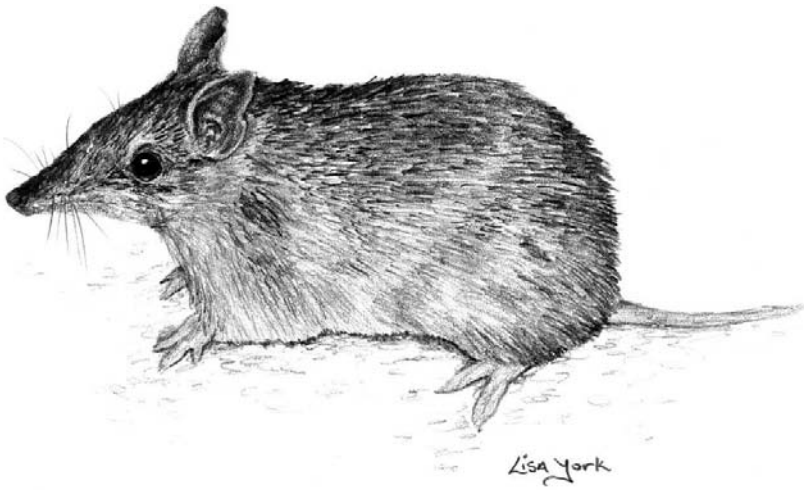
WESTERN BARRED BANDICOOT *Perameles bougainville*, BURROWING BETTONG *Bettongia lesueur* and BANDED HARE-WALLABY *Lagostrophus fasciatus* RECOVERY PLAN 2007 - 2011.



Wildlife Management Program No. 49

Australian Government

Department of Environment and Conservation

Our environment, our future

WESTERN BARRED BANDICOOT, BURROWING BETTONG AND BANDED HARE-WALLABY RECOVERY PLAN
2007 –2011

Prepared by

Dr Jacqueline D. Richards

For the Western Barred Bandicoot, Burrowing Bettong and Banded Hare-wallaby Recovery Team, Department of Environment and Conservation (Western Australia), and the Australian Government Department of the Environment, Water, Heritage and the Arts.

December 2007

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Cover illustration of the western barred bandicoot drawn by Lisa York. Reproduction is prohibited without the prior written permission of the author of this Recovery Plan.

FOREWORD

Recovery Plans are developed within the framework laid down in Department of Conservation and Land Management (CALM) Policy Statements Nos 44 and 50, and the Australian Government Department for the Environment, Water, Heritage and the Arts *Revised Recovery Plan Guidelines for Nationally Threatened Species and Ecological Communities* (Environment Australia 2002).

Recovery Plans delineate, justify and schedule management actions necessary to support the recovery of threatened species and ecological communities. The attainment of objectives and the provision of funds necessary to implement actions are subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery Plans do not necessarily represent the views or the official position of individuals or organisations represented on the Recovery Team.

A multi-species approach to recovery planning is supported by the Department for the Environment, Water, Heritage and the Arts (DEWHA) (*Revised Recovery Plan Guidelines for Nationally Threatened Species and Ecological Communities 2002*), where species occur in the same area and have closely related requirements based on their habitats, threats or recovery actions. This Recovery Plan was approved by the Department of Environment and Conservation, Western Australia. Approved Recovery Plans are subject to modification as dictated by new findings, changes in status of the taxon or ecological community and the completion of recovery actions. The provision of funds identified in this Recovery Plan is dependent on budgetary and other constraints affecting the Department, as well as the need to address other priorities.

Information in this Recovery Plan was accurate at February 2007.

CONTENTS

SUMMARY

***Perameles bougainville bougainville,* western barred bandicoot (Shark Bay island subspecies).**

Family:	Peramelidae
Common name:	Marl
DEC Region:	Midwest
DEC District:	Shark Bay
Shire:	Shark Bay
Current status of taxa:	Endangered
Habitat requirements:	Open habitat with some ground cover

***Bettongia lesueur lesueur,* burrowing bettong (Shark Bay island subspecies).**
***Bettongia lesueur* unnamed subspecies, burrowing bettong (Barrow Island subspecies).**

Family:	Macropodidae
Common name:	Boodie
DEC Region:	Midwest, Pilbara
DEC District:	Shark Bay, Pilbara
Shire:	Shark Bay, Ashburton
Current status of taxa:	*B. l. lesueur* Vulnerable, *B. l.* unnamed subspecies Vulnerable
Habitat requirements:	Open habitat with some ground cover and soil suitable for the construction of warrens

***Lagostrophus fasciatus fasciatus,* banded hare-wallaby (Shark Bay island subspecies).**

Family:	Macropodidae
Common name:	Merrnine or Munning
DEC Region:	Midwest
DEC District:	Shark Bay
Shire:	Shark Bay
Current status of taxa:	Vulnerable
Habitat requirements:	Areas of dense heath and shrub thickets
Recovery Team:	Shark Bay Marsupials Recovery Team
Overall objective:	Ensure the survival and improve the status of the Shark Bay island subspecies of the western barred bandicoot (currently 'Endangered' under the EPBC Act and the IUCN Red List 2000) within 20 years to a level that will enable downlisting to 'Vulnerable', based on the IUCN (1994) criteria of extent of occurrence**.** Ensure the survival and maintain the status (currently 'Vulnerable' under the EPBC Act and the IUCN Red List 2000) of the Bernier and Dorre Island subspecies of the

burrowing bettong and banded hare-wallaby and Barrow Island subspecies of the burrowing bettong.

Recovery Plan criteria

This Recovery Plan will be deemed successful if:

- The estimated total number of individuals known to be alive on Bernier, Dorre, Barrow and Boodie Islands does not decline to levels below that of natural population fluctuations (natural population fluctuations to be defined as part of this process); and
- The number of individuals known to be alive in captivity does not decline, other than through the sourcing of translocated populations.

This Recovery Plan will be deemed to have failed if:

- The estimated total number of individuals known to be alive on Bernier, Dorre, Barrow and Boodie Islands declines to levels below that of natural population fluctuations;
- The number of individuals known to be alive in captivity declines to a level below that of natural population fluctuations; and
- Less than three introduced predator-free mainland or island populations are initiated within five years for each of the three species.

Recovery actions

1. Protect the wild populations and their habitat;
2. Maintain captive populations;
3. Investigate the disease status of captive and wild western barred bandicoot populations and develop a strategy for disease control;
4. Maintain existing reintroduced populations;
5. Reintroduce western barred bandicoots, burrowing bettongs and banded hare-wallabies to suitable mainland and island sites (if available);
6. Review taxonomic status and genetic structure of threatened Shark Bay marsupials with comparisons made to other related taxa as required;
7. Use population viability analysis (PVA) to compare the viability of wild and current and potential reintroduced populations;
8. Enhance community participation and education;
9. Secure ongoing funding for the implementation of the Recovery Plan; and
10. Enhance linkages between projects involved in the recovery of western barred bandicoots, burrowing bettongs and banded hare-wallabies.

1. BACKGROUND

1.1 Taxonomy and description of species

Western barred bandicoot

The western barred bandicoot was first described from a specimen taken at Peron Peninsula in Shark Bay by naturalists Quoy and Gaimard on the *Uranie* in 1817. Populations of the species have been referred to by a variety of names including *Perameles bougainville*, *P. bougainville bougainville*, *P. bougainville notina*, *P. arenaria*, *P. myosura myosura*, *P. myosuros myosuros*, *P. myosura notina*, and *P. fasciata* (Gould 1844, 1863; Krefft 1866; Glauert 1933; Wakefield 1963; Friend 1990; Friend and Burbidge 1995). This has created some confusion in the taxonomy of the group. The mainland forms are now extinct and few specimens exist in museums, providing little opportunity to clarify the past nomenclature. All these forms are now regarded as *P. bougainville* (Freedman 1967; Friend 1990; Friend and Burbidge 1995).

There are currently two subspecies recognised: *P. bougainville bougainville* on Bernier and Dorre Islands, and the extinct mainland form *P. bougainville myosura* (Maxwell *et al*. 1996). No studies have been carried out on the genetic structuring of this species, and limited morphological data suggest that the current classification is appropriate (Short *et al.* 1998).

The western barred bandicoot is a member of the Family Peramelidae, and is one of the long-nosed bandicoots of the genus *Perameles*. It is the smallest bandicoot species, with an average weight of 219 g (Short *et al*. 1998). It is solitary and nocturnal, sheltering during the day in concealed nests. Nests are made in a small hollow dug amongst litter under shrubs. Litter, grasses and other vegetation are used to line an inner chamber. Bandicoots emerge at late dusk to forage for insects and other small animals, seeds, roots and herbs obtained by digging or hunting (Friend and Burbidge 1995; Visser 2000). The species has been extinct on mainland Australia since the 1930s (Brooker 1977; Copley *et al.* 1989; Richards and Short 2003), but survives on Bernier and Dorre Islands in Shark Bay, Western Australia.

Western barred bandicoots are lightly built animals with large erect ears. Their feet are elongated, with the second and third toes of the hind feet being syndactylus (partially fused) and reduced in size, while the fourth toe is long and strongly clawed. Their fur is grizzled, brown-grey in colour, and they are distinguished by darker brown-black bars radiating downwards over the sides of the body from the back. The chin, throat, belly, tops of the feet, and the inner part of the limbs are white (Jones 1923-25; Ovington 1978).

Burrowing bettong

The burrowing bettong was first described by naturalists Quoy and Gaimard in 1824, from a specimen collected on Dirk Hartog Island in Shark Bay by Freycinet on the *Uranie* in 1817. Several forms have been identified, including *Bettongia lesueur lesueur* from Bernier and Dorre Islands, and an undescribed subspecies from Barrow and Boodie Islands (those from Boodie Island were unintentionally eradicated in 1985

during a program to rid the island of black rats, and reintroduced from Barrow Island in 1993 (Morris 2002)). The extinct mainland subspecies have been referred to as *B. l. graii* from south-west Western Australia and *B. lesueur harveyi* from the Eyre Peninsula of South Australia (Waterhouse 1846); however, the validity of this nomenclature is not generally accepted (Burbidge 1995). Recently, old museum specimens collected in 1885 from Charleville, Queensland were reanalysed and taxonomically corrected as *Bettongia lesueur* (Van Dyck 2005). *B. lesueur graii* is regarded as the only mainland subspecies by the IUCN (2004). Common names include the "boodie" and "boodie-rat", and the Pitjantjatjara from central Australia knew the species as "mitika" or "tjunku" (Shortridge 1909; Burbidge *et al.* 1988).

Dorre Island animals are typically larger than those on Bernier Island. Barrow Island animals are considerably smaller than those on the Shark Bay islands and the island animals appear to be smaller than their former mainland counterparts (Short and Turner 1999). Felicity Donaldson, a PhD student from the University of Western Australia, has been conducting research to examine this taxonomy, using mitochondrial DNA and morphological data. Preliminary findings suggest that differences between Barrow and Dorre Island animals may be enough for separation of the two populations at the species level, according to Wiens and Penkrot's key, which is based upon the Evolutionary Species Concept (Wiley 1978; Wiens and Penkrot 2002; F. Donaldson[1] personal communication).

The burrowing bettong is a rat-kangaroo and a member of the Family Potoroidae. They are nocturnal and omnivorous, and are social animals, living in communal warren systems (Sander *et al*. 1997). They are unusual in that they are the only macropod to build and inhabit burrows. They are medium-sized, with an average weight of 1300 g on Bernier and Dorre Islands (Short and Turner 1999), and 750 g on Barrow Island (F. Donaldson[1] personal communication). The last museum record of their occurrence on mainland Australia was in 1942 in south-western WA (Kitchener and Vicker 1981); however, there is evidence of their persistence until the 1960s in central Australia (Burbidge *et al.* 1988). Wild populations survive on Bernier and Dorre Islands in Shark Bay, and on Barrow and Boodie Islands in Western Australia.

Burrowing bettongs are characterised by a short blunt head, with small rounded and erect ears. They are yellowy-grey in colour, though the ventral surface tends to be lighter, while the legs, feet and tail are more yellow in colour (Jones 1923-25). In some animals the tail has a distinctive white tip.

Banded hare-wallaby

William Dampier first described the banded hare-wallaby in 1699. The species was assigned to the monotypic genus *Lagostrophus* by Thomas (1886) due to differences in external characters to other hare-wallabies in the genus *Lagorchestes*. It is the only survivor of the large group of at least 20 species of 'sthenurine' (short faced kangaroo) macropods that existed in the Pleistocene (Flannery 1983), characterised by their lower and upper incisors biting together. Three subspecies have been described: *Lagostrophus fasciatus fasciatus* from Bernier, Dorre and possibly Dirk Hartog Islands, *L. fasciatus albipilis* from the south-west of Western Australia and *L. fasciatus baudinettei* from South Australia, New South Wales and Victoria (Thomas

[1] Felicity Donaldson, PhD student, Department of Animal Biology, UWA.

1886; Maxwell *et al.* 1996; Helgen and Flannery 2003). The latter subspecies was described in 2003. Both the Dirk Hartog Island and the mainland populations are presumed extinct. The last specimens from mainland Western Australia were collected from the Pingelly area in 1906 (Shortridge 1909; Short and Turner 1992) while the last South Australian specimen was collected in 1927 (Helgen and Flannery 2003). It was known as "merrnine" or "munning" in the south-west of Western Australia (Shortridge 1909).

Animals on Dorre Island have a shorter pes length than those on Bernier Island but no other morphological, chromosomal or blood allozyme differences between the two island populations have been found (Courtenay 1993; Richards *et al*. 2001). This lack of difference provides support for the existing taxonomy, which does not distinguish between the two island populations.

The banded hare-wallaby is characterised by a series of dark transverse bands across its lower back and rump, which led to its first description by William Dampier in 1699 as "a Sort of Raccoon". In all other species of hare-wallabies, and all other macropods, the rumps are unbanded, and the lower incisors bite behind the upper incisors.

Little of the biology and habits of the banded hare-wallaby are known, due to its rapid demise from the mainland after European settlement. The Bernier and Dorre Island populations have provided the opportunity to study the species in their natural habitat. Adults weigh an average of 1600 g and there is no sexual dimorphism (Richards *et al.* 2001). They are herbivorous, and dependent upon dense thickets of shrubs and heath for shelter (Short and Turner 1992).

1.2 Distribution and habitat

Western barred bandicoot

Western barred bandicoots were widely distributed across the southern mainland of Australia at the time of European settlement but have survived only on Dorre and Bernier Islands in Shark Bay, Western Australia (Figures 1 and 2). They occurred in a broad arc from Onslow on the north-west coast of Western Australia, through the Western Australian Wheatbelt, Nullarbor Plain, and arid and semi-arid South Australia, Victoria and New South Wales to the Liverpool Plains in New South Wales. At the time of the collection of the first specimen at Peron Peninsula in Shark Bay they were regarded as "common" (Quoy and Gaimard 1824 in Ride and Tyndale-Biscoe 1962).

The last records of the species on mainland Australia were at Mt Crombie in South Australia in 1931, at Rawlinna in Western Australia in 1929, and at Ooldea in South Australia in 1922 (Figure 1; Kitchener and Vicker 1981; Copley *et al.* 1989; Friend 1990). It was apparently common in the Ooldea area in the 1920s (Gara 1996; Boscacci *et al.* 1997). Finlayson (1961) regarded it as 'a well known and fairly plentiful species' in the Anangu Pitjantjatjara Lands of South Australia in 1932-35 (Copley *et al.* 2003).

Remnant populations of western barred bandicoots on Dorre and Bernier Islands are small (2200 - 4400 combined minimum population estimate for both islands) and

subject to substantial fluctuations due to weather (Short and Turner 1993; Short *et al.* 1997a). Day use of Bernier Island is permitted, though overnight recreational use is prohibited and Dorre Island is a 'prohibited area' with access by permission only (Hancock *et al.* 2000).

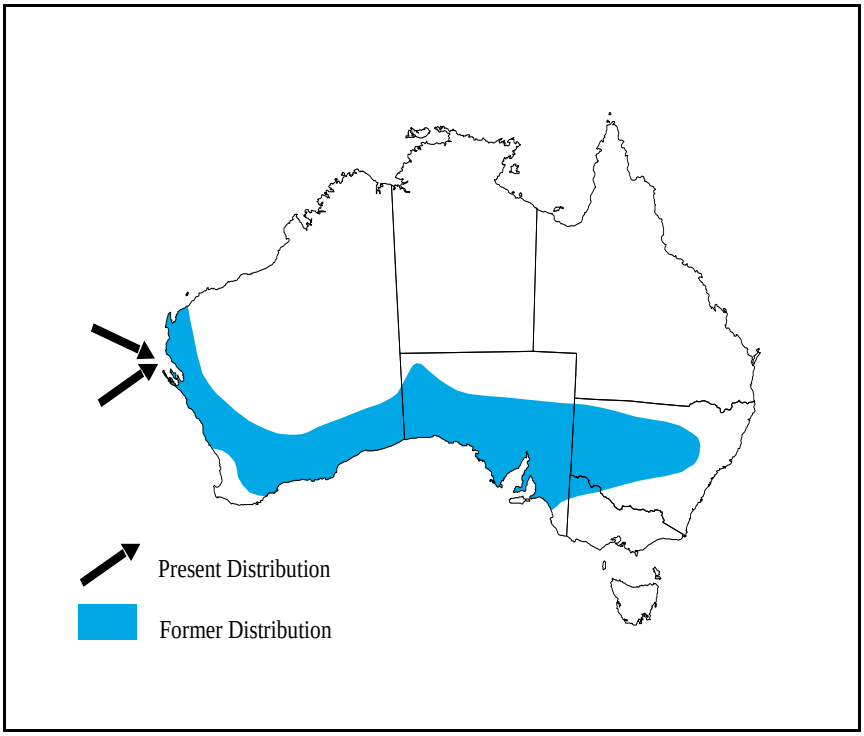

Figure 1: Past and present distribution of wild populations of the western barred bandicoot (adapted from Strahan (1995), and including historical and subfossil records). Arrows indicate Bernier and Dorre Islands.

The western barred bandicoot was reintroduced to Heirisson Prong at Shark Bay, Western Australia in 1995 (Richards and Short 1997; Richards and Short 2003), to the Arid Recovery Reserve at Roxby Downs in South Australia in 2000 (Arid Recovery Project 2002; Arid Recovery 2004), and to Faure Island in Shark Bay in October 2005 (Table 1). The first two of these reintroduced populations have been extant for 10 years and five years respectively and represent a significant advancement in recovery efforts for this threatened species. A captive population is housed at the Return to Dryandra Field Breeding Facility (Table 2).

The western barred bandicoot was an inhabitant of a wide variety of vegetation types within the southern arid and semi-arid zones of Australia. The type specimen was found on Peron Peninsula at the foot of elevated dunes by Quoy and Gaimard in 1817 (Ride and Tyndale-Biscoe 1962). Gould (1863) described the range of *P. myosurus* in Western Australia as "inhabits the whole line of coast of the Swan River colony, but, so far as I can learn, is not found to the westward of the Darling Range of hills. It resides in the densest scrub, thickets of the seedling *Casuarinae* being its favourite resort." They lived in open saltbush, bluebush and *Acacia* plains, broken by sandhills and limestone outcrops in the western portion of central Australia (Jones 1923-25).

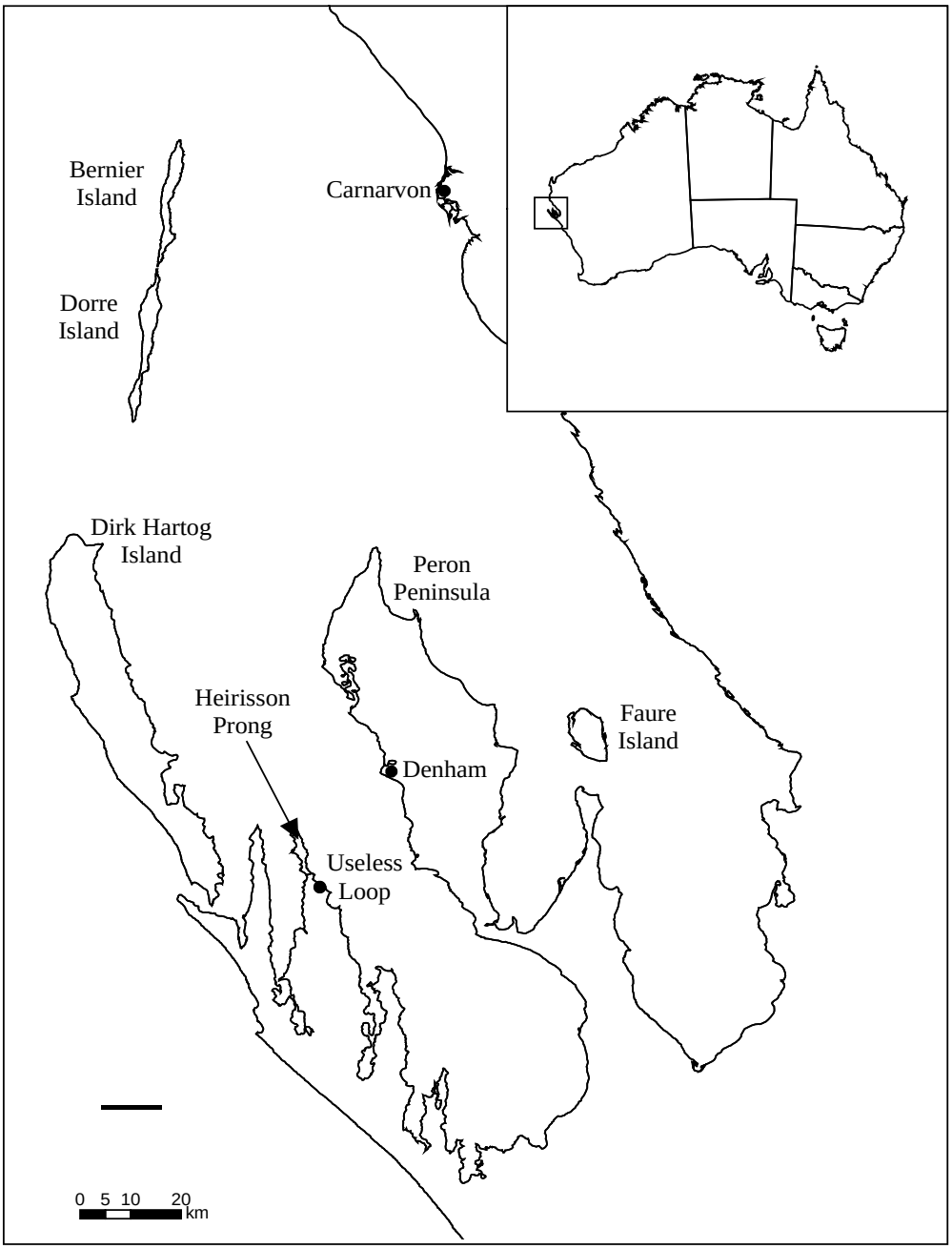

Figure 2: Shark Bay, Western Australia, showing the location of Bernier and Dorre Islands (with wild populations of western barred bandicoots, burrowing bettongs and banded hare-wallabies) and Heirisson Prong, Peron Peninsula (François Peron National Park) and Dirk Hartog and Faure Islands (sites of proposed and established reintroductions). Inset shows the location of Shark Bay.

Table 1: Summary of source, translocations (date of initial release) and recent minimum population size (numbers trapped) of reintroduced populations of the western barred bandicoot, burrowing bettong and banded hare-wallaby. Data from Short *et al.* (1992), Short and Turner (2000), Richards and Short (2003), Arid Recovery (2004), C. Sims[2], N. Thomas[3], N. Marlow[4], K. Morris[5], J. Richards[6], J. Bentley[7], J. Short[8], K. Newport[9] and K. Moseby[10] (personal communication). HPFBF = Heirisson Prong Field Breeding Facility, DFBF = Dryandra Field Breeding Facility, ARR = Arid Recovery Reserve, PCBC = Peron Captive Breeding Centre. [#]ARR bandicoot population first released in 2000, but recaptured and quarantined at Adelaide Zoo, re-released 2001. *Population size estimated only. [@]Yookamurra animal's original source from Bernier/Dorre Islands.

Species	Location	Source	Number acquired (date)	Population (date assessed)
Western barred bandicoot	Heirisson Prong	HPFBF/Dorre	14 (1995) 2 (1996)	500 (May 2006)
	ARR	Bernier	12 ([#]2001)	40+ (December 2006)
	Faure Island	Heirisson Prong	20 (October 2005)	17 (July 2006)
Burrowing bettong	Yookamurra	[@]Breeding pens	10 (1995) 30 (1996) 2 (2001) 19 (2004)	0 (May 2005)
	Gibson Desert	Barrow	40 (1992)	0 (1993)
	Heirisson Prong	HPFBF/Dorre	42 (1992-1995)	50 (May 2006)
	Faure Island	Heirisson Prong	17 (2002)	260 (July 2006)
	ARR	Bernier Heirisson Prong	10 (1999) 19 (2000)	400 (December 2006)
	Boodie Island	Barrow Island	36 (1993)	*200+ (2000)
	Dryandra Woodland	DFBF	23 (2003) 14 (2004)	0 (May 2005)
	Scotia	Yookamurra	30 (2004) 90 (2005)	140 (December 2006)
Banded hare-wallaby	Dirk Hartog Island	Dorre	21 (1978)	0 (1980)
	François Peron NP	PCBC	18 (2001)	0 (April 2003)
	Faure Island	PCBC	7 (2004) 9 (2005) 10 (2006)	40 (July 2007)

[2] Dr Colleen Sims, Project Eden Coordinator, Shark Bay District, DEC Denham.
[3] Neil Thomas, Principal Technical Officer, DEC Perth.
[4] Dr Nicky Marlow, Senior Research Scientist, DEC Perth.
[5] Keith Morris, Manager, Biodiversity Conservation Group, DEC, Perth.
[6] Dr Jacqueline Richards, Regional Ecologist, AWC, West Perth.
[7] Dr Joss Bentley, Regional Ecologist, AWC, Scotia Wildlife Sanctuary, NSW.
[8] Dr Jeff Short, Director, Wildlife Research and Management, Perth.
[9] Karl Newport, Arid Recovery Project and BHP Billiton, Roxby Downs, South Australia.
[10] Katherine Moseby, Arid Recovery Project, Roxby Downs, South Australia.

Table 2: Summary of source, translocations and recent minimum population size (numbers trapped) of current captive breeding populations of the western barred bandicoot, burrowing bettong and banded hare-wallaby. Data from N. Thomas[3], N. Marlow[4], K. Moseby[11], A. Dugand[11], J. Bentley[7], J. Short[8], and C. Sims[2] (personal communication), Arid Recovery Project (2001), and Mawson (2004). DFBF = Dryandra Field Breeding Facility, PCBC = Peron Captive Breeding Centre.

Species	Location	Source	Number acquired (date)	Population (date assessed)
Western barred bandicoot	DFBF	Bernier/Dorre	27 (1998)	13 (December 2006)
Burrowing bettong	DFBF	Dorre	20 (1998)	90 (December 2006)
	University of Adelaide	DFBF	14 (2001/02)	10 (2005)
	Yookamurra	Bernier	10 (1995)	65 (January 2007)
		DFBF	8 (2000)	
	Scotia	Yookamurra	16 (1997-2000)	0 (2006)
Banded hare-wallaby	PCBC	Bernier	25 (1998)	39 (January 2007)
	DFBF	Dorre	18 (1998)	1 (January 2007)
		PCBC	4 (2004)	

Gould (1863) thought that the western barred bandicoot was more common in the "interior", in the country within the ranges, than in the area between the mountains and the sea in eastern and southern Australia. On the western slopes of New South Wales they were recorded from the stony ridges, which branch off from the ranges towards the Darling and Namoi Rivers. In South Australia they were found on the stony ranges and spurs, which ran down to the "bend of the Murray River", and in the vast open plains near the head of St Vincent's Gulf (Gould 1863).

The two remaining populations on islands in Shark Bay have been extensively studied (e.g. Ride and Tyndale-Biscoe 1962; Friend and Burbidge 1995; Short *et al.* 1998). Trapping and spotlighting throughout Bernier and Dorre Islands suggested that western barred bandicoots were widely distributed throughout the islands in all habitats, but were most likely to be found in tall scrub (Short *et al.* 1998). At night they were commonly found in the sandhills and were seen occasionally during the day amongst low, dense scrub (Ride and Tyndale-Biscoe 1962). Friend and Burbidge (1995) reported that they were common in the scrub associated with stabilised dunes behind the beaches and also occurred on the open steppe associations.

Burrowing bettong

Burrowing bettongs were widely distributed across the southern two-thirds of mainland Australia at the time of European settlement (Figure 3). Their distribution ranged from north-west Western Australia to the western slopes of New South Wales near Bourke (Short 1998; Short 1999a). Van Dyck (2005) provided evidence that the historic range extended through to south-western Queensland, with specimens collected near Charleville in the late 1800s. The last records of the species on

[11] Alison Dugand, South West Regional Manager, AWC, Karakamia Wildlife Sanctuary, Chidlow, WA.

mainland Australia were in the 1920s in New South Wales (Frith 1973) and in the Flinders Ranges in the 1940s (Tunbridge 1991). Finlayson (1958) thought that the burrowing bettong was common in the Musgrave and Everard Ranges area until 1940. Burbidge *et al.* (1988) suggested that the species may have persisted in the central Australia deserts until the 1960s, and Finlayson (1961) wrote that burrowing bettongs had "now been almost eliminated' from north-western South Australia.

The species now occurs naturally only on Bernier, Dorre, Barrow and Boodie Islands (Figures 3 and 4; Short and Turner 1993). These remnant populations are small (600 - 2500 per island) and subject to substantial fluctuations due to weather (Short *et al.* 1997a). These two island populations and the Barrow Island populations have been extensively studied (e.g. Ride and Tyndale-Biscoe 1962; Short and Turner 1989, 1993, 1994, 1999; Short *et al.* 1997a).

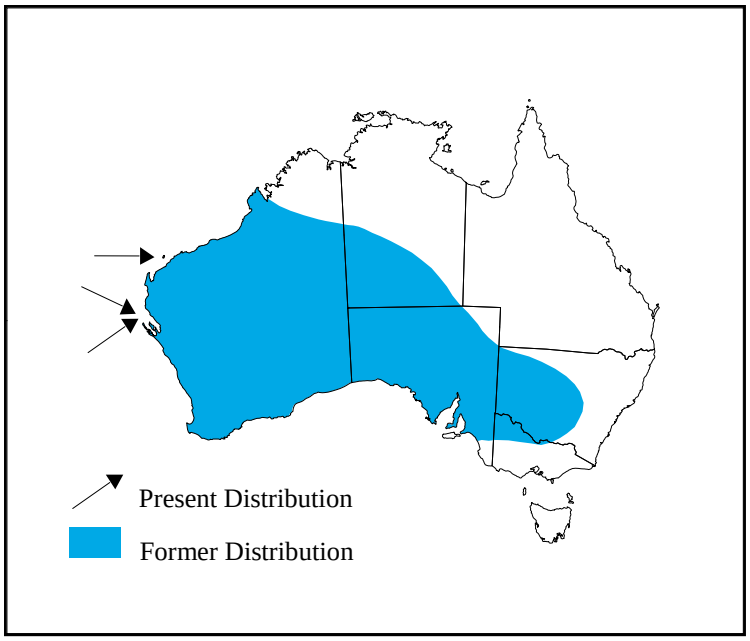

Figure 3: Past and present distribution of wild populations of the burrowing bettong (adapted from Strahan (1995), and including historical and subfossil records). Arrows indicate Bernier, Dorre, Barrow and Boodie Islands.

The species was reintroduced from Dorre Island to Heirisson Prong at Shark Bay in 1992, where it has been extensively studied also (Short *et al.* 1994; Sander *et al.* 1997; Robley 1999; Short 1999a; Short and Turner 2000; Robley *et al.* 2001, 2002; Parsons *et al.* 2002b; Freegard *et al.* in press). It was also reintroduced from Barrow Island to Boodie Island in 1993 after their accidental eradication in 1985 during a rat-baiting program (Morris 2002). Further reintroductions occurred from Heirisson Prong to the Arid Recovery Reserve at Roxby Downs in 1999 (Arid Recovery Project 2002; Arid Recovery 2004) and Faure Island in 2002, and from Yookamurra to Scotia Wildlife Sanctuary in 2004 (Table 1). All these populations are likely to be self-sustaining if the sites can be maintained free of exotic predators.

Figure 4: Barrow Island, showing the location of the five DEC mammal trapping grids used between 1998 and 2003 (map courtesy of Chevron and DEC).

Other reintroductions include from the Lake Phillipson area of South Australia to Kangaroo Island in 1924 (Finlayson 1958), from Barrow Island to the Gibson Desert in 1992 (Christensen and Burrows 1994), and from Bernier Island to Yookamurra Sanctuary in South Australia in 1995, 1996, 2001 and 2004 (Short *et al.* 1992; Short and Turner 2000; J. Bentley[7] personal communication). These were all unsuccessful. Captive populations are currently held at the Dryandra Field Breeding Facility and Yookamurra and Scotia Wildlife Sanctuaries, sourced from Dorre Island and the University of Adelaide, Bernier and Dorre Islands, and Yookamurra respectively (Table 2). A small number of animals have been housed at the University of Adelaide (and nearby Cleland Wildlife Park) for cross-fostering trials (D. Taggart[12] personal communication).

The former distribution of the burrowing bettong suggests that it occurred in a wide variety of open habitat types (Seebeck *et al.* 1989), including the *Triodia* desert (Short 1999a) sandhill and claypan country (Jones 1923-25; Finlayson 1958), and saltbush scrub on limestone karst (Richards and Short 1996). Burrowing bettongs occupy all habitats throughout Bernier and Dorre Islands, including low heath, scrub and *Triodia* (Short and Turner 1993). They were trapped in greatest numbers in sandplain with *Triodia* habitat and dune with heath (Short and Turner 1999). On Barrow Island the species is widely distributed across the island but is absent in areas where nearby sites for construction of warrens are limited due to rocky substrate (Short and Turner 1994). At the Arid Recovery Reserve they prefer to dig their warrens on the dune slopes or in limestone calcrete outcrops, but forage throughout all habitats (Arid Recovery Project 2002; K. Moseby[11], personal communication).

Banded hare-wallaby

Banded hare-wallabies formerly occurred in an arc through the south-west of Western Australia and had a dependence on dense shrub cover (Prince 1995; Figure 5). Shortridge (1909) noted that the species occurred at Eucla, the Laverton area and the Pilbara; however, Helgen and Flannery (2003, p. 201) suggested that Shortridge's collected sight records "lie well outside the known subfossil range of *L. fasciatus* and could be spurious". They were last recorded on mainland Australia in 1906 in Western Australia (Shortridge 1909; Short and Turner 1992) and 1927 in South Australia (Helgen and Flannery 2003). Their fossil remains extended across the Nullarbor Plain (Lundelius 1957; Baynes 1987), through parts of southern South Australia (Helgen and Flannery 2003) and into south-eastern Australia in Victoria and New South Wales (Wakefield 1964; Marshall 1974).

They have survived as wild populations only on Dorre and Bernier Islands in Shark Bay, Western Australia. The combined island populations were estimated at approximately 7,800 in 1988/89 (Short and Turner 1992) and 9,700 in 1991/92 by Short *et al.* (1997a).

[12] Dr David Taggart, Mammal Department, Adelaide Zoo, SA.

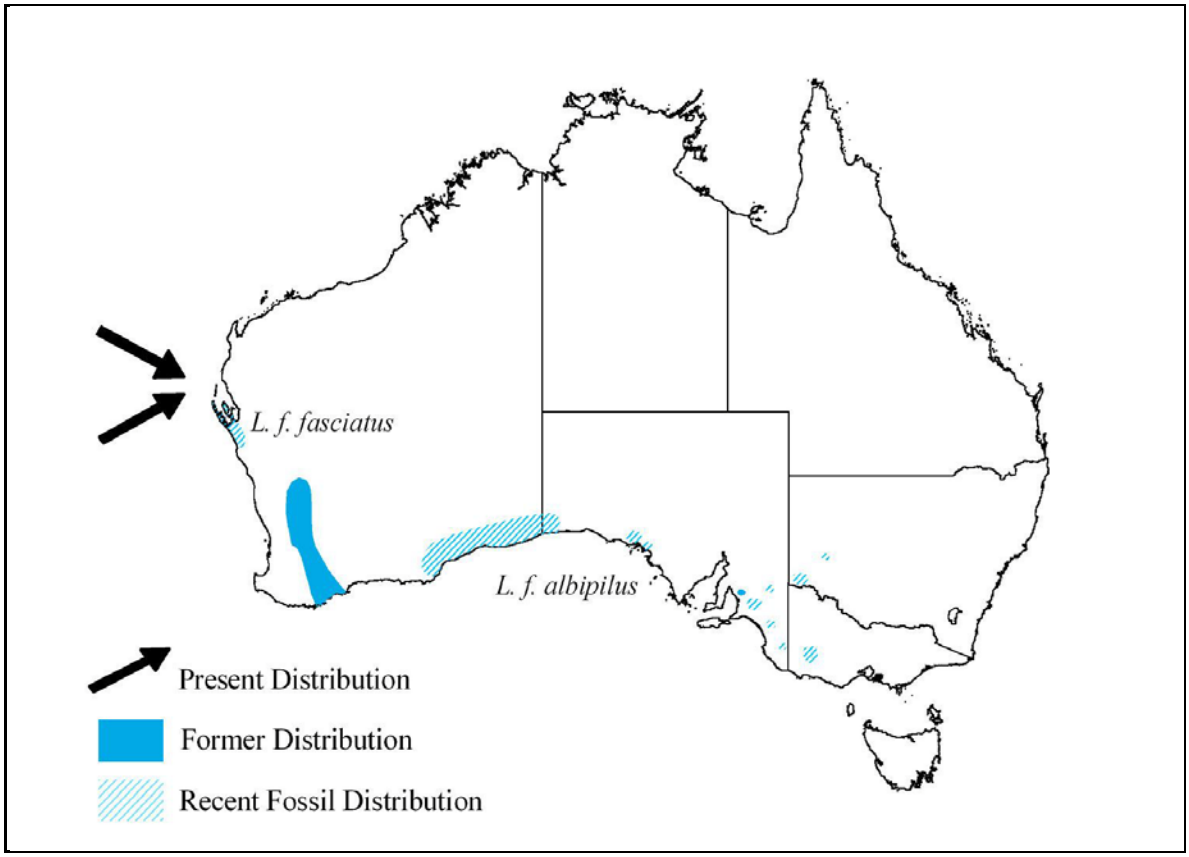

Figure 5: Past and present distribution of the banded hare-wallaby (adapted from Strahan (1995), and including historical and subfossil records). Arrows indicate Bernier and Dorre Islands.

Banded hare-wallabies were reintroduced to Dirk Hartog Island by DEC (then the Fisheries and Wildlife Department) in 1974 (Burbidge and George 1978; Short *et al*. 1992). They were held in an enclosure on Dirk Hartog Island until 1978 when they were released to free-range across the island. No animals were seen after 1980 when the project was abandoned (Short *et al.* 1992). The lack of success of the reintroduction was thought to be due to a combination of predation by feral cats and wedge-tail eagles, intensive browsing by sheep and goats, and a period of drought over the summer of 1979/80, resulting in the loss of 30-40% of the *Acacia* shrub cover (Short *et al*. 1992). A recent reintroduction to Peron Peninsula at Shark Bay in 2001 failed due primarily to cat predation (Morris *et al.* 2004; Hardman 2006). Captive populations are currently held at the Peron Captive Breeding Centre and Barna Mia in Dryandra Woodland (Table 2). A successful introduction of banded hare-wallabies to Faure Island was conducted by AWC with animals from PCBC in 2004, with additional animals translocated in 2005 and 2006. The introduction appears to be successful in the short-term.

J. Gilbert (in Gould 1863) reported that the banded hare-wallaby was found only "in densely thick scrubs, on flats and on the edges of swamps, where the small brush *Melaleuca* grows so thickly, that it is almost impossible for a man to force his way through; its runs being under this, the animal escapes even the quick eye of a native". The species formerly occupied areas of dense cover in *Eucalyptus* woodlands in

south-western Australia (Shortridge 1909). Banded hare-wallabies were apparently plentiful in the early days of settlement of the Swan River Colony. Gould (1863) noted that Aboriginals were in the habit of burning the prickly thickets of scrub that hare-wallabies inhabited, and "by this means destroy very great numbers" of animals, which were not easily captured in any other way.

On Bernier and Dorre Islands they are dependent on thick scrub for shelter, and are concentrated along the consolidated dunes that run the length of the island and along the travertine of the west coast. They shelter in small groups amongst dense thickets of vegetation dominated by *Acacia ligulata*, *A. coriacea*, *Alectryon oleifolium*, *Diplolaena dampieri*, and *Ficus platypoda* (Short and Turner 1992). Peron and Lesueur found this species "among the impenetrable low thickets of *Mimosa*" on Bernier Island (Gould 1863).

1.3 Conservation status

The western barred bandicoot is listed as nationally Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and the burrowing bettong and banded hare-wallaby are classified as Vulnerable under the EPBC Act. Under this Commonwealth legislation, species listed as threatened (which include the Endangered and Vulnerable categories) are considered to be matters of national environmental significance. Actions that have, will have, or are likely to have, a significant impact on a listed threatened species are not to be undertaken without approval from the Commonwealth Minister for the Environment, Water, Heritage and the Arts.

The World Conservation Union (IUCN) lists the western barred bandicoot as Endangered, and the burrowing bettong and banded hare-wallaby as Vulnerable (IUCN 2004), as does the Action Plan for Australian Marsupials and Monotremes (Maxwell *et al.* 1996).

Each of the species is listed under Schedule 1 'Fauna that is likely to become extinct or is rare' under Section 14(2)(ba) of the Western Australian *Wildlife Conservation Act 1950*.

1.4 Biology and ecology relevant to threatening processes

Western barred bandicoot

Diet

The most commonly consumed prey items found in the faecal matter of reintroduced bandicoots at Heirisson Prong were beetles, grasshoppers and crickets. Larvae, Hemipteran bugs, spiders, earwigs, ants, millipedes, and centipedes were regularly consumed, and plant matter (seeds, berries) and skinks were eaten also (Visser 2000).

Krefft (1866, p.16) commented that "they proved as useful as cats. The *Perameles* would tumble the mice about with its fore paws, break their hind legs, and eat generally the head only. I have seen a single individual kill as many as twenty mice in a very short time, breaking their bones successively, after which it would begin to satisfy its hunger." The "mice" were probably the desert mouse *Pseudomys desertor*

or Bolam's mouse *P. bolami* (J. Seebeck[13], personal communication). In captivity at the Peron Captive Breeding Centre a number of instances of consumption of house mice *Mus musculus* have been recorded. Pieces (head, leg or digestive tract material) of mice have been found in western barred bandicoot pens, and one bandicoot was observed attacking the hindquarters of a mouse stuck under a partition (N. Noakes[14], personal communication).

Reproduction

Western barred bandicoots have eight nipples, produce one to three young per litter (usually two), and can have up to four litters per year (Richards and Short 2003). The average litter size on Bernier and Dorre Islands is 1.8 (Short *et al.* 1998). Gestation is thought to be 12.5 days (as for other bandicoot species), and the period of pouch life is 60 - 70 days. Young are weaned 1 - 2 weeks after vacation of the pouch. Females reach sexual maturity at about 175 g, and males a little later at about 195 g (Short *et al.* 1998).

Breeding on the islands appears to be strongly seasonal, peaking over winter when the majority of rain falls. The onset of breeding appears to be triggered by the first substantial rain in autumn, following summer drought. Reintroduced animals at Heirisson Prong may breed continuously if environmental conditions are good and individuals have survived and bred for up to four years (Richards and Short 2003).

Western barred bandicoots in the Return to Dryandra enclosure are capable of breeding throughout the year; however, the majority of females breed between May and December, peaking between June and September (33% of females had young or were lactating in summer, 21% in autumn, 67% in winter and 48% in spring (N. Thomas unpublished data). Most females breed twice a year with only a very few producing three litters per year (N. Thomas unpublished data).

Rate of increase following drought

Bandicoot numbers on trapping grids on Dorre Island increased substantially in three years from October 1988 to September 1991 after a period of drought prior to April 1989. The population doubled on average each 1.07 years with a rate of increase of 0.65 (Short *et al.* 1998). During a similar time period from August 1989 to August 1992, bandicoots on Bernier Island increased only slightly, showing little sign of recovery (Short *et al.* 1998). Bandicoots reintroduced to Heirisson Prong increased at a rate of 0.54 over a three-year period to 1999 in the presence of a low-density feral cat population (Richards and Short 2003) followed by a period of more rapid increase at a rate of 1.08 in a subsequent three-year period to 2006 where cats were only occasionally present (J. Short unpublished data).

Movements

Most recorded movements by western barred bandicoots on Bernier and Dorre Islands were less than 400 m; however, males have been recorded moving up to 1020 m over one day between trapping locations, and females up to 490 m over a two-day period (Short *et al.* 1998). Friend and Burbidge (1995) reported home range sizes for male and female western barred bandicoots on Dorre Island of 2.5 and 1.4 ha (at high

[13] John Seebeck, deceased, formerly with Arthur Rylah Institute, Department for Sustainability and Environment, Victoria.

[14] Nicole Noakes, Project Eden Officer, DEC, Denham.

density) and 14.2 and 6.2 ha (at low density), respectively. The home range of both male and female bandicoots overlapped, with 51% of traps capturing more than one bandicoot. Home ranges of males overlapped more than females, with up to five males captured at a single trap location over a four-day period of trapping (Short *et al.* 1998). The maximum number of females captured during this same time period and at a single trapping location was two (Short *et al.* 1998).

The movements of reintroduced western barred bandicoots at Heirisson Prong after their release did not pose significant problems for their re-establishment. One bandicoot moved four kilometres from the release site but the majority remained within one kilometre of their release site (Richards and Short 2003).

Survival and longevity

Mortality of reintroduced western barred bandicoots at Heirisson Prong appeared high. Thirty-seven percent of all animals released from the predator-free refuge to free-range on the 12 km^2 peninsula were not captured after the first month, 39% of young recruited into the free-range population were not recaptured after their first capture, and a further 26% recaptured once only (Richards and Short 2003). The longest surviving free-range bandicoot was at least four years and three months of age, though mean longevity was eight months for males and 10 months for females (Richards and Short 2003). At Dryandra Field Breeding Facility western barred bandicoots have survived for up to 4.5 years (N. Thomas unpublished data) and at Kanyana Native Fauna Rehabilitation Centre one has survived in captivity to eight years of age (J. Butcher[15] personal communication). Movement of bandicoots away from the trap lines at Heirisson Prong may have resulted in an underestimate of survival and longevity. Suggested causes of apparent mortality include predation by feral cats, wedge-tailed eagles, Gould's monitors, king brown snakes *Pseudechis australis*, owls, intraspecific aggression, and dispersal beyond the reintroduction site (Richards and Short 2003).

Tolerance to sodium monofluoroacetate

Western barred bandicoots are thought to possess a high tolerance to sodium monofluoroacetate ('1080' poison), commonly used in the control of foxes and rabbits in Australia, particularly Western Australia (King 1988). There are no published results for the western barred bandicoot; however, other species of bandicoot tested (*Perameles nasuta*, *P. gunnii* and *Isoodon obesulus*) survived doses of between 5.4 to 7.7 mg/kg of 1080 (McIlroy 1983). Despite the high tolerance to 1080, western barred bandicoots may be at risk from accidental poisoning during fox, cat, and rabbit control programs due to their small body size, particularly with the use of poisoned 'One-shot' oats.

Burrowing bettong

Diet

Burrowing bettongs are regarded as omnivorous, consuming a wide variety of foods, including tubers, bulbs, seeds, stems, nuts (*Santalum acuminatum*), grasses, and invertebrates, and have been seen scavenging carcasses (Shortridge 1909; Finlayson 1958; Robley *et al.* 2001). On Barrow Island food consumed included the fruit of native figs, seeds, roots, termites and fungi (Burbidge 1995). Robley *et al.* (2001)

[15] June Butcher, Manager, Kanyana Native Fauna Rehabilitation Centre

found that the winter diet of reintroduced burrowing bettongs at Heirisson Prong was comprised predominantly of hypogeal fungi, fruit, seed, forbs, and arthropods, and in summer their diet consisted of browse from shrubs such as *Acacia ligulata*, *Senna chatelainiana*, *Eremophila* spp., *Pimelea microcephala*, and *Olearia* spp., fruit, seed, stem, and some forbs. Rabbit hair was found in their faecal matter in summer, and burrowing bettongs were sighted at rabbit carcasses, suggesting that they may scavenge dead rabbits (Robley *et al.* 2001). There was evidence of digging by burrowing bettongs in turtle nesting hollows at Dorre Island, suggesting they were scavenging on eggs and/or hatchlings (C. Sims[2], personal communication).

Reproduction

Burrowing bettongs on Bernier and Dorre Islands have two nipples, produce a single young, and are able to produce three young per year (Tyndale-Biscoe 1968). F. Donaldson[1] (personal communication) has observed four nipples in most females on Barrow Island. Two incidences of twinning have been recorded in the reintroduced population at Heirisson Prong, one in the reintroduced population at Faure Island, and a fourth on Barrow Island (F. Donaldson[1] personal communication). The oestrous cycle is 23 days, gestation is 21 days, and the period of pouch life is 113 - 120 days. Young are weaned 23 - 74 days after vacation of the pouch (Tyndale-Biscoe 1968). Females reach sexual maturity at about 885 g on Bernier and Dorre Islands (about 7 - 8 months of age; Short and Turner 1999), and as early as 645 g on Heirisson Prong (Short and Turner 2000).

Breeding on Bernier and Dorre Islands may be continuous but typically is broken by a period of anoestrous over summer (Short and Turner 1999). Breeding commences with the first major rainfall (>20 mm) and peaks over winter when the majority of rain falls. On Barrow Island, reproductive output is seasonally opposite to Shark Bay and there appears to be a peak in breeding in summer coinciding with cyclonic rain (F. Donaldson[1] personal communication). Reintroduced animals at Heirisson Prong may breed continuously, though there was a peak between February and September (80% of adult females with young) and some evidence of a decline in breeding in late spring and early summer (30-60% of females with young; Short and Turner 2000).

Within the Return to Dryandra enclosure, burrowing bettongs breed all year round, with a slight reduction in breeding effort over January/February and a peak in August (37% of females had young or were lactating in summer, 48% in autumn, 62% in winter and 54% in spring (N. Thomas unpublished data). Females were able to produce between two to three young per year with only a few being able to produce four (N. Thomas unpublished data).

Group size

Reintroduced burrowing bettongs on Heirisson Prong formed associations of one male and one to many females in warrens, but tend to forage independently at night (Sander *et al.* 1997). On Barrow Island groups are formed between multiple males and females and groups tend to be much larger, sometimes over 100 individuals (F. Donaldson[1] personal communication).

Rate of increase following drought

Burrowing bettong numbers on trapping grids on Dorre Island increased substantially after a period of drought. The observed rate of increase (r) was 0.75, resulting in an

approximate doubling of the population over a 12-month period (Short and Turner 1999).

Movements

Through radio tracking studies, Robley (1999) found that the average home range size of burrowing bettongs at Heirisson Prong was 107 and 86 ha for males and females respectively, and Short and Turner (1989) found that the average home range size on Barrow Island was 133 and 98 ha respectively. The average home range size for reintroduced animals on Faure Island was 101 ha (F. Donaldson[1] personal communication).

Parsons *et al.* (2002b) found that young male burrowing bettongs reintroduced at Heirisson Prong dispersed significantly further than young females, with mean dispersal distances of 4,600 m and 1,100 m respectively. The young animals dispersed between the ages of 170 and 250 days, coinciding with the period associated with weaning to sexual maturity.

Survival and longevity

Longevity for burrowing bettongs in the wild on Bernier and Dorre Islands was over three years for some animals (Short and Turner 1999), and in the reintroduced population at Heirisson Prong has been up to eleven years (J. Short *et al.* unpublished data). Major episodic losses in the Heirisson Prong population were typically a result of predation by a fox gaining entry to the site (Short and Turner 2000; Short *et al*. 2002). Predation by cats has also resulted in a decrease in survival of the reintroduced bettongs, through the loss of young at foot, and also through predation on adults (Short and Turner 2000; J. Short unpublished data).

Tolerance to sodium monofluoroacetate

Burrowing bettongs have a high tolerance to sodium monofluoroacetate. Animals tested survived doses of up to 10-20 mg/kg of 1080 (McIlroy 1982), suggesting that burrowing bettongs should be at little risk from accidental poisoning during fox, cat, and rabbit control programs.

Banded hare-wallaby

Diet

Banded hare-wallabies are herbivorous, consuming grasses, malvaceous and leguminous shrubs and other dicotyledonous plants (Prince 1995), by grazing and browsing. In captivity at the Peron Captive Breeding Centre, banded hare-wallabies have been regularly observed browsing on *Acacia sclerosperma, A. tetragonophylla, A. ramulosa*, and *A. ligulata* (C. Sims[2], personal communication). They will eat leaves (live and dead), bark, flowers and seed pods of many of these species.

Reproduction

Banded hare-wallabies are polyoestrous, monovular and have a post-partum oestrous (Tyndale-Biscoe 1965). They carry a single pouch young, and usually produce one per year, occasionally two (one case of twins has been recorded in 9 years at PCBC) if environmental conditions are particularly favourable (Richards *et al.* 2001). Their gestation period is thought to be about 30 days within the Peron Captive Breeding Centre (C. Sims[2], personal communication), and varies between 20 to 42 days for similar sized macropods (Tyndale-Biscoe and Renfree 1987). In captivity at the

Peron Captive Breeding Centre pouch life is about six months, with up to another 1 - 2 months as young at foot and still suckling (C. Sims[2], personal communication). The smallest female carrying pouch young on Bernier and Dorre Islands weighed 1,000 g (Richards *et al.* 2001) and in captivity at the Peron Captive Breeding Centre as small as 550 g (C. Sims[2], personal communication). Sexual maturity of males is likely to occur at about 1500 g (Richards *et al*. 2001).

Breeding on Dorre and Bernier Islands appeared to occur throughout the year, with some indication of a peak in the autumn (75% of adult females carrying pouch young or lactating) and a seasonal decrease in the latter half of the year (62% in winter, 50% in spring, 33% in summer; Richards *et al*. 2001). The beginning and end of the breeding season did not appear to correspond with time of year. In captivity at the Peron Captive Breeding Centre most births appear to occur in the first half of the year, with a peak in January, though breeding can continue throughout the year (C. Sims[2], personal communication). Hardman (2006) recorded most new pouch young in April and May in the reintroduced animals in François Peron National Park.

Banded hare-wallabies in the Return to Dryandra enclosure usually bred between March and September (93% of females had young or were lactating in autumn, 44% in winter/early spring) and typically only produced one young per year (N. Thomas unpublished data).

Survival and longevity

Banded hare-wallabies can survive in the wild for at least five or six years (Richards *et al.* 2001), and were thought to live 4 - 5 years on Bernier Island, on the basis of ages estimated from dentition and skull measurements (Hughes 1965). In captivity at the Peron Captive Breeding Centre animals have survived for ten years (C. Sims[2], personal communication).

Movements

The average home range of a small sample of banded hare-wallabies reintroduced to François Peron National Park was 11 ha (Hardman 2006).

Tolerance to sodium monofluoroacetate

Banded hare-wallabies were found to possess a high tolerance to sodium monofluoroacetate. Animals tested survived doses of up to 100-125 mg/kg of 1080 (McIlroy 1982), suggesting that banded hare-wallabies should be at no risk from accidental poisoning during fox, cat, and rabbit control programs.

1.6 International obligations

The western barred bandicoot, burrowing bettong and banded hare-wallaby are listed under the CITES Convention on International Trade in Endangered Species of Wild Fauna and Flora (1975) Appendix I (2003), as species threatened with extinction for which international trade in specimens of these species is permitted only in exceptional circumstances.

The western barred bandicoot, burrowing bettong and banded hare-wallaby all occur within the Shark Bay World Heritage property, inscribed in 1991 and maintained under the World Heritage Convention, and are an important component of one of the

four natural criteria for which the area is listed. The Uluṟu-Kata Tjuṯa National Park, site of the planned reintroduction of burrowing bettongs to an enclosure, is also World Heritage listed. Actions that have, will have, or are likely to have, a significant impact on the world heritage values of a declared World Heritage property are not to be undertaken without approval from the Commonwealth Environment Minister. To obtain approval, the action must undergo a rigorous environmental assessment and approval process. The world heritage values of a property are "the natural heritage and cultural heritage contained in the property" (Convention Concerning the Protection of the World Cultural and Natural Heritage 1972).

The primary management objectives for World Heritage properties, which are part of Australia's general obligations under the World Heritage Convention, are:

a) to protect and conserve the World Heritage values of the property;
b) to integrate the protection of the area into a comprehensive planning program;
c) to give the property a function in the life of the Australian community;
d) to strengthen appreciation and respect of the property's values through education; and
e) to take appropriate scientific, technical, legal, administrative and financial measures necessary for achieving these objectives.

1.7 Affected interests

Department of Environment and Conservation (Western Australia)

The Department of Environment and Conservation (Western Australian; DEC) is responsible for conserving the rich diversity of native plants, animals, natural ecosystems and many of the unique landscapes of Western Australia. DEC is responsible for the conservation of all native species in Western Australia, whatever their location.

In particular, DEC is responsible for the management of Bernier, Dorre, Barrow and Boodie Islands, and the François Peron National Park, and their resident wild, captive and reintroduced populations of threatened mammals. DEC manage a program, *Project Eden*, that aims to reconstruct and rejuvenate an entire ecosystem on the 105,000-hectare Peron Peninsula, by controlling introduced predators and reintroducing a suite of native fauna (Morris *et al.* 2004; Hardman and Moro 2006).

DEC are also responsible for the management of the 24,000-hectare Dryandra Woodland, its surrounding area, the Dryandra Field Breeding Facility and the animal viewing enclosure ‘Barna Mia’, 160 km south-east of Perth in the Wheatbelt region of Western Australia. *The Dryandra Woodland Management Plan 1995 – 2005* (Friend *et al.* 1995) proposed the reintroduction of native animals that were once found in Dryandra, and the *Return to Dryandra* project was established in order to reintroduce threatened marsupials, including the western barred bandicoot, burrowing bettong and banded hare-wallaby, and create a source of animals for reintroduction into other areas. The *Return to Dryandra* project is particularly significant due to the proximity to Perth and the presence of remnant central Wheatbelt vegetation and fauna (e.g. numbat *Myrmecobius fasciatus*, woylie *Bettongia penicillata*, red-tailed phascogale *Phascogale calura*, chuditch *Dasyurus geoffroii* and tammar wallaby *Macropus eugenii*) that has been lost from the majority of the region (Friend *et al.* 1995).

Both *Project Eden* and *Return to Dryandra* fall under the umbrella of *Western Shield*, a major fox control program instigated by DEC in 1996 over an area of 3.5 million hectares of land in Western Australia (primarily in National Parks, Nature Reserves and State forest) (Possingham *et al.* 2004). *Western Shield* aims to maximise the recovery of native fauna by the control of foxes and feral cats, to reintroduce locally extinct species of native mammal and to involve rural communities in fox control (Possingham *et al.* 2004; Wyre 2004).

Australia's general obligations under the World Heritage Convention are outlined in the 'International obligations' section above. The lead agency for managing the Shark Bay World Heritage property is DEC.

The maintenance of a Recovery Team and the formal submission of this Recovery Plan for the species outlined in this report for adoption under the EPBC Act is the responsibility of DEC.

Australian Wildlife Conservancy

The Australian Wildlife Conservancy (AWC) is a "national, independent, non-profit organisation committed to saving Australia's native wildlife from the very real threat of extinction" via a national network of sanctuaries managed for conservation, scientific research and public education (Australian Wildlife Conservancy 2002a). AWC is responsible for the management of a number of properties throughout Australia, including Faure Island in Western Australia, a 5,800-hectare pastoral lease within the Shark Bay World Heritage Property, with resident introduced populations of western barred bandicoots, burrowing bettongs and banded hare-wallabies. The island is free of introduced predators and rabbits.

AWC are responsible also for the management of the 5,000-hectare Yookamurra Wildlife Sanctuary in South Australia, and 65,000-hectare Scotia Wildlife Sanctuary in New South Wales, both of which have populations of burrowing bettongs, which reside in four-hectare predator-proof enclosures at Yookamurra (formerly within a 1,100-hectare enclosure) and a larger 4,000-hectare fenced area at Scotia. The intention at these properties is to establish free-ranging and self-sustaining populations of these species within large enclosures. Plans for expansion of the fenced area at Scotia Wildlife Sanctuary are underway, with an additional 4,000-hectare area due for completion and reintroduction of burrowing bettongs in 2007/8, and a third area of similar size at a later date.

Useless Loop Community Biosphere Project Group Inc.

The Useless Loop Community Biosphere Project Group Inc. (ULCBPG) is responsible for the management of Heirisson Prong and its resident reintroduced populations of the burrowing bettong and western barred bandicoot (Short and Turner 2000; Richards and Short 2003; Richards *et al.* 2004). Heirisson Prong is a 1,200-hectare peninsula fenced at its base to exclude introduced predators (Short *et al.* 1994). It is dedicated to nature conservation, education and recreation (Short 1999b). Conservation efforts are a result of a partnership between the ULCBPG and local mining company Shark Bay Salt Joint Venture (SBSJV), and CSIRO Sustainable Ecosystems until 2005, when Wildlife Research and Management took over the CSIRO component of the project.

Arid Recovery Project

The Arid Recovery Project (ARP) is responsible for the management of the 8,600-hectare Arid Recovery Reserve near Roxby Downs in South Australia and its resident reintroduced populations of burrowing bettong and western barred bandicoot. Introduced predators and rabbits have been eradicated from 6,000 ha of the reserve, and control is ongoing in the remaining 2,600-hectare Red Lake expansion area (Arid Recovery 2004). The project aims to facilitate ecological restoration of an arid ecosystem through partnerships between mining, pastoral, tourism and conservation organisations. Other aims include researching the restoration of ecological processes and providing opportunities for education and training (Arid Recovery Project 2002). Conservation efforts are a result of a partnership between the local community, BHP Billiton (formerly WMC Resources), the South Australian Department for Environment Heritage and the University of Adelaide.

Tourism

Tourism is recognised as the fastest growing industry in the Shark Bay region and is focussed strongly on the region's unique natural environment. Tourism accounted for 26% of economic activity in the Gascoyne region in 2002; greater than mining (16%, predominantly salt and gypsum), retail trade (13%), fishing (9%), agriculture (6%, including horticulture and pastoralism), and construction (2%; Department of Local Government and Regional Development and the Gascoyne Development Commission 2003). Dorre Island is currently inaccessible to tourists and Bernier Island is accessible for day visits by boating traffic in the area (usually local). François Peron National Park is accessible to tourists and has seen an increase in the number of visitors since the inception of *Project Eden* from 10,000 during the 1993/4 financial year to 51,034 during the 2001/2 financial year (DEC Denham visitor statistics). A long-standing aim of the region has been to increase the length of stay of tourists by providing opportunities to view a variety of native wildlife, in addition to the highly visited dolphins at Monkey Mia. DEC has run annual *Landscope Expeditions* to Peron Peninsula to assist with *Project Eden*, the most recent in 2006. Opportunities to view some of the local reintroduced and extant mammalian and reptilian fauna are currently being provided as a part of school holiday seminars and activities held at Monkey Mia and in Denham. In addition, an ever expanding volunteer and school groups program provides the opportunity for the general public to participate in some of *Project Eden*'s fauna recovery programs.

DEC's Barna Mia is the only facility that has the western barred bandicoot, burrowing bettong and banded hare-wallaby all on display to the public. The facility has had an annual visitor growth rate of 25% with 2,500 people visiting the facility in the 2004/05 financial year and is a particularly important resource for public education.

It is likely that an increased awareness of the plight of the western barred bandicoot, burrowing bettong and banded hare-wallaby, combined with the opportunity to view the animals in their natural habitat, will enhance the attraction of the Shark Bay region and Dryandra woodland as tourist destinations. Actions associated with the recovery of the threatened marsupials are unlikely to impact negatively on tourism. The status of existing nature reserves is unlikely to change in their level of accessibility.

However, there is likely to be an increase in opportunities for ecotourism in areas such as Francois Peron National Park, Dryandra Woodland and Dirk Hartog Island.

Mining

WMC Resources supported the Arid Recovery Project (ARP) near Roxby Downs in South Australia from 1997 to 2005, by providing infrastructure and financial assistance to assist in the re-establishment of western barred bandicoot and burrowing bettong populations. BHP Billiton acquired WMC Resources in 2005 and is continuing to support the ARP. However, a proposal to expand the Olympic Dam mine at Roxby Downs has the potential to affect the Arid Recovery Project (P. Copley[16] personal communication), which is bordered by the Olympic Dam Special Lease to the south, and is situated partly on the Olympic Dam Mine Lease and adjoining pastoral properties leased by BHP Billiton (Arid Recovery 2004).

Recovery of western barred bandicoots and burrowing bettongs occurs within the vicinity of salt harvesting operations carried out by Shark Bay Salt Joint Venture (SBSJV) at Useless Loop in Shark Bay, Western Australia. The mining company supports a number of recovery actions related to the reintroduction of these two threatened mammals adjacent to their existing mining lease, and within their current pastoral lease, by providing infrastructure and financial assistance. The majority of actions associated with the recovery of the threatened mammals are unlikely to impact negatively on mining interests in the region. However, in areas where introduced predators are controlled, rabbit numbers may increase and affect the efficacy of mine site rehabilitation via the destruction of vegetation and soil erosion due to warren construction, and increase nutrient input into ponds utilised in the salt-production process via rabbits drowning. Rabbit control measures such as 1080 baiting, myxomatosis and the Rabbit Calicivirus Disease may assist in reducing the impact of rabbits within the mine site.

Pastoral

Recovery of the western barred bandicoot and burrowing bettong occurs within the existing pastoral leases of Carrarang Station and Faure Island in Western Australia. Dirk Hartog Island in Shark Bay is currently being transferred from a pastoral lease to conservation estate, after DEC proposed a contract of purchase and associated change in land tenure from pastoral lease to national park (see 'Benefits to other species' section below), which was completed in 2005. Actions associated with the recovery of the western barred bandicoot, burrowing bettong and banded hare-wallaby are generally unlikely to have a negative impact on pastoral activities at these locations as conservation goals have typically displaced pastoralism.

Broad scale fox control may offer benefits in terms of pastoral production, by reducing the loss of livestock. For example, Carrarang, Tamala, Nanga and Coburn Pastoral Leases in the Shark Bay region have existing 1080 baiting programs to control foxes to protect livestock. However, it is likely that populations of threatened mammals would benefit from the eradication of introduced livestock (sheep and goats) at all current and potential reintroduction sites, including Dirk Hartog Island. The increasing importance of the sustainable harvest of feral goats to the economy of

[16] Peter Copley, Senior Ecologist, Department for Environment and Heritage, SA.

several pastoral properties in the area may result in the maintenance of high population levels. This in turn, would have the potential to adversely affect conservation of any reintroduced populations of marsupials on adjacent conservation estate by compromising control efforts in these areas.

Local communities

It is likely that many of the actions associated with the recovery of the western barred bandicoot, burrowing bettong and banded hare-wallaby outlined within this Recovery Plan may increase community knowledge, pride and involvement in the conservation of the threatened mammal species and their habitat. In particular, opportunities for employment would be well received.

A World Heritage Interpretive Centre was constructed at Denham in Shark Bay in 2006 and is likely to assist in promoting community support and participation, as does the Barna Mia animal viewing enclosure at Dryandra Woodland. Actions outlined within this Recovery Plan are unlikely to impact negatively on the resident human communities within the Shark Bay region, in particular the township of Denham, and the mining community of Useless Loop, in the Narrogin region of Western Australia, and at Roxby Downs in South Australia.

The community of Useless Loop has restrictions on the presence of unsterilised domestic cats. Denham residents are offered a subsidy to provide sterilisation of their cats. Both communities are educated about the presence and use of 1080 poison in the region. The Useless Loop community has also maintained a policy that no new domestic cats are to be brought to the community. It is important to maintain community education for new residents, and any changes to current practice would require investment in community consultation, to prevent tension often associated with domestic cat control policies and the distribution of 1080 poison. The use of 1080 has resulted in the death of domestic dogs at Useless Loop and Denham, and reduces the accessibility of locations within pastoral leases for recreational pursuits with pets.

The Shark Bay Shire Council are not involved directly with the conservation of the western barred bandicoot, burrowing bettong and banded hare-wallaby that occur in the region, but maintain a community-based interest and support for the recovery of these species (B. Cane[17] personal communication).

Staff of Chevron that work on Barrow Island have had the opportunity to become directly involved with the monitoring of the island fauna and are made aware of the conservation significance of the island at their induction.

Other organisations

Other organisations involved, or with the potential to become involved, in the conservation and management of the western barred bandicoot, burrowing bettong and banded hare-wallaby, either directly within the Shark Bay region and Barrow and Boodie Islands where wild populations occur, via translocations of animals sourced

[17] Bryan Cane, Shark Bay Shire Councilor and Vice President of the ULCBPG Inc.

from the Shark Bay region, through animal husbandry, conservation education, research interests or providing funding include:

- Kanyana Wildlife Rehabilitation Centre Inc., Perth, Western Australia;
- Department for Environment and Heritage (DEH), South Australia.
- University of Adelaide, South Australia.
- Department for the Environment, Water, Heritage and the Arts, Canberra, Australian Capital Territory.
- WWF - Australia.
- Threatened Species Network, Perth (TSN), Western Australia.
- University of Queensland.
- Murdoch University, Western Australia

1.8 Role and interests of indigenous people

Implementation of recovery actions under this plan will include consideration of the role and interests of indigenous communities in the region, and this is discussed in the recovery actions. Input and involvement will be sought from any indigenous groups that have an active interest in areas that are habitat for the western barred bandicoot, burrowing bettong or banded hare-wallaby.

The Aboriginal Sites Register maintained by the Department of Indigenous Affairs lists significant sites on Bernier and Dorre Islands in Shark Bay (Site IDs 7123 and 7124), due to the presence of skeletal material, burial sites and artefacts/scatter, and on Barrow Island (Site ID 8951) due to the presence of artefacts/scatter. Significant sites also occur in the vicinity of potential translocation sites on Heirisson Prong, Dirk Hartog Island, Dryandra and Peron Peninsula (Site IDs 3273, 3275, 6129, 6221, 6222, 6223, 6224, 6225, 6498, 10024, 10727, 11049), due to the presence of skeletal material, burial sites, man-made structures, artefacts/scatter, middens/scatter and a quarry. Not all significant sites are listed on the Register.

There are indigenous people, as defined by the EPBC Act, residing in the communities of Denham and Useless Loop in Shark Bay, including members of the Yadgalah Aboriginal Corporation based in Denham. Brian Clarke, Manager of the Yadgalah Aboriginal Corporation, was consulted in August 2005 and expressed an interest in being aware of actions associated with the recovery of the western barred bandicoot, burrowing bettong and banded hare-wallaby and their habitat outlined in this Recovery Plan, similar to that of other members of the Shark Bay community (as described in the 'Affected interests' section above).

Two indigenous people from outside the Shark Bay region have been employed and trained by CSIRO to assist with management of the Heirisson Prong project. The Yadgalah Aboriginal Corporation was involved in the early stages of this process. The DEC Indigenous Trainee program has employed indigenous personnel at Shark Bay, whose work programs have included involvement in a number of *Project Eden* activities. The Indigenous Australian Hoult family from Denham were the previous leaseholders of Faure Island, and have maintained an association with AWC, assisting in the management of access to the island and the maintenance of island infrastructure.

Traditional owners, the Anangu, and members of the Mutijulu Community have been involved in the Uluru - Kata Tjuta National Park Species Reintroduction Project since its inception in the 1990s. The rufous hare-wallaby *Lagorchestes hirsutus* was reintroduced in September 2005 and there are plans to reintroduce the burrowing bettong or 'mitika' in 2006 (Gillen *et al.* 1999).

1.9 Benefits to other species

Actions associated with the recovery of the western barred bandicoot, burrowing bettong and banded hare-wallaby may benefit a wide range of other native fauna and flora species, particularly at reintroduction sites.

The control of introduced predators at reintroduction sites will benefit many critical weight range mammal species (small to medium sized mammals weighing between 35 and 5,500 grams, many of which have declined or become extinct in the last 200 years since European settlement of Australia; Burbidge and McKenzie 1989). Predator control may facilitate reintroductions of other species of threatened fauna. For example, greater stick-nest rats *Leporillus conditor* have been reintroduced at Heirisson Prong (Richards *et al.* 2001), malleefowl *Leipoa ocellate,* woylies *Bettongia penicillata,* quenda *Isoodon obesulus* and greater bilbies *Macrotis lagotis* at Peron Peninsula (Morris *et al.* 2004), greater bilbies to Dryandra Woodland (N. Marlow[4] personal communication), greater bilbies and greater stick-nest rats at the ARP (Arid Recovery Project 2002; Arid Recovery 2004), greater bilbies, bridled nailtail wallabies *Onychogalea fraenata* and brush-tailed bettongs *Bettongia penicillata* at Scotia Wildlife Sanctuary, and Shark Bay mice and greater stick-nest rats at Faure Island (Australian Wildlife Conservancy 2002b). Numerous threatened mammals have been reintroduced by DEC at other Western Shield sites throughout Western Australia, providing substantial conservation benefits to the nation (Mawson 2004).

The pale field rat *Rattus tunneyi* has increased in distribution and abundance since the control of introduced predators at Heirisson Prong and the adjacent Carrarang Station, and now represents one of the last remaining arid/semi-arid zone populations of the species. The abundance of a number of species of native marsupial and rodent (little long-tailed dunnart *Sminthopsis dolichura,* ash grey mouse *Pseudomys albocinereus* and sandy inland mouse *Pseudomys hermannsburgensis*) had increased at Heirisson Prong as a direct benefit of fox and cat control, compared with the loss of small mammals in adjacent areas with fox control only (Risbey *et al.* 2000).

Predator control on Peron Peninsula has been associated with increased abundance of a number of reptile species (e.g. Gould's monitor *Varanus gouldii,* bobtail skink *Tiliqua rugosa,* thorny devil *Moloch horridus*), the echidna *Tachyglossus aculeatus,* and several other threatened species that occur in the region (e.g. thick-billed grasswren *Amytornis textilis textilis,* woma python *Aspidites ramsayii*; C. Sims[2], personal communication).

The ARP has significantly more vegetative cover and five times the population of small native mammals inside the reserve compared to sites outside the reserve, particularly spinifex hopping mice *Notomys alexis* and Bolam's mice *Pseudomys bolami* (Arid Recovery 2004).

There are a number of possible negative impacts of recovery actions outlined in this report on non-target species or ecological communities, including the uptake of new, more palatable cat baits by non-target species, the potential for the introduction of disease at reintroduction sites, and the impact of fox and cat baiting programs on the population dynamics of native and introduced fauna. Monitoring to determine the uptake and impact of novel baits by non-target species is required prior to any wide-scale use of baits for management of feral cats. Research into non-target bait uptake has been proposed by Algar and Burrows (2004) and will be conducted prior to the registration of the novel sausage cat bait. Initial studies have suggested that non-target bait uptake is likely to be minimal (Algar and Burrows 2004). The development of a eutherian-specific toxin is under way (T. Peacock[18] personal communication). Its use would negate issues surrounding non-target uptake of baits. Broadscale baiting for foxes and dingos in Australia, particularly in the arid zone, has led to changes in the abundance of feral cats and rabbits (e.g. Christensen and Burrows 1994; Risbey *et al.* 1999, Short and Turner 2000, Robley *et al.* 2002), which in turn has altered interactions between introduced species and native fauna. Land managers must take into consideration the interactions between native and introduced fauna and their habitats, many of which are unknown, when implementing predator control.

A disease risk management strategy has recently been developed by DEC that will benefit a broad spectrum of native species (Chapman *et al.* 2005).

1.10 Social and economic impacts

Mining

The actions outlined in this report are in general unlikely to impact negatively on existing mining operations undertaken by SBSJV on Heirisson Prong. However, there is concern about the critical build up of rabbits as a result of predator management, as described above in the 'Affected interests' section.

Pastoral

The success of reintroductions to pastoral areas such as Edel Land may be impaired by existing pastoral activities on Carrarang Station. In particular, populations of free-ranging goats and sheep may not be compatible with retaining the vegetative cover that is necessary for harbouring native fauna and conferring protection from predators; whether it is species that are nationally threatened or locally abundant. Pastoral activities on Dirk Hartog Island and Faure Island may be incompatible with the conservation of threatened marsupials. However, this will cease to be an issue with a change in land tenure on Dirk Hartog Island to conservation estate, and given the conservation objectives of the current leaseholders of Faure Island (AWC) is unlikely to be of concern.

Tourism

Tourism is now regarded as the major industry in Shark Bay (Reark Research *et al.* 1995). Dorre Island is currently inaccessible to tourists but this being revised to day

[18] Dr Tony Peacock, Chief Executive, Invasive Animals Cooperative Research Centre.

use. Bernier Island is accessible for day visits by boating traffic in the area (usually local) but overnight camping does occur. This raises concerns about the western barred bandicoots on Dorre Island being contaminated with papilloma/polyoma virus from Bernier Island. There are also concerns about the risk of wildfire from campfires, particularly in drought conditions when perhaps >50% of the vegetation is dead and dry. Heirisson Prong is accessible only to local residents and their visitors. In previous years, the Useless Loop community and CSIRO hosted international Earthwatch Institute visits to Heirisson Prong; however, this program ceased in 2002. DEC has run a number of Landscope Expeditions to Peron Peninsula. Faure Island is currently inaccessible to tourists but future plans (beyond the next five years) could include the implementation of a managed visitor program (Australian Wildlife Conservancy 2002b).

Peron Peninsula is accessible to tourists and has seen an increase in the number of visitors since the inception of *Project Eden* from 10,000 during the 1993/4 financial year to 31,034 during the 2001/2 financial year (DEC Denham visitor statistics). A long-standing aim has been to increase the length of stay of tourists in the region by providing opportunities to view a variety of native wildlife, in addition to the highly-visited dolphins at Monkey Mia.

2. HABITAT CRITICAL TO THE SURVIVAL OF THE SPECIES

The maintenance of habitat on Bernier and Dorre Islands is critical to the survival of the western barred bandicoot, burrowing bettong and banded hare-wallaby. Habitat on Boodie and Barrow Islands is critical to the survival of the burrowing bettong. Potential habitats that present opportunities for reintroduction of one or more of these species include a number of sites that have been managed for the conservation of threatened species for a number of years: Heirisson Prong managed by the ULCBPG with assistance from SBSJV and Wildlife Research and Management (ex-CSIRO staff), Peron Peninsula and Dryandra Woodland managed by DEC, and Faure Island, Yookamurra and Scotia Wildlife Sanctuaries managed by AWC, the Arid Recovery Project at Roxby Downs managed by the ARP, and BHP Billiton and the South Australian Department for Environment and Heritage, community and government partnership. All these conservation sites have programs to control introduced predators, represent locations within the past range of all or some of the western barred bandicoot, burrowing bettong and banded hare-wallaby, and either have reintroduced, or have plans to reintroduce one or more of these three species. At all these sites, and any others to be considered in the future, the control of introduced predators is a necessity, and management to ensure adequate vegetative cover is important.

Western barred bandicoot

Habitat critical to the survival of the western barred bandicoot is likely to include areas of dense ground cover to avoid predators, with leaf litter for constructing nests, and a minimum of introduced predators. Reintroduced western barred bandicoots at Heirisson Prong are distributed throughout the 12 km^2 peninsula (Richards and Short unpublished data). At the Arid Recovery Reserve the species survives in very open country, suggesting that their habitat requirements may be quite flexible in the absence of introduced predators. They appear to show a preference for nesting in the denser dunes at the Arid Recovery Reserve but will forage at night out in the more open chenopod swales (K. Moseby[11], personal communication; Arid Recovery 2004).

Burrowing bettong

Habitat critical to the survival of the burrowing bettong is likely to include areas of open habitat with some ground cover and soil suitable for the construction of warrens. It was thought that foxes need to be absent and feral cats controlled to low levels (Short and Turner 2000); however, the recent loss of the majority of the reintroduced population of burrowing bettongs at Heirisson Prong in the presence of feral cats (Short unpublished data), suggests that both foxes and cats need to be eradicated completely.

Banded hare-wallaby

Habitat critical to the survival of the banded hare-wallaby is likely to include areas of dense heath and shrub thickets to avoid native predators. Sites that might have suitable habitat include Faure Island, Peron Peninsula and Edel Land in Shark Bay, and conservation reserves in the south coastal region of Western Australia. However, banded hare-wallabies are unlikely to persist at sites where introduced predators are present.

2.1 Mapping of habitat critical to the survival of the species

The maintenance of all habitats on Bernier and Dorre Islands is critical to the survival of the western barred bandicoot, burrowing bettong and banded hare-wallaby, as outlined in the 'Habitat critical to the survival of the species' section above. Western barred bandicoots and burrowing bettongs occupy all habitats throughout Bernier and Dorre Islands, and while banded hare-wallabies favour areas with thick scrub for shelter, they were still found in lower numbers throughout much of the remainder of the islands (Short and Turner 1992; Short and Turner 1993; Short *et al.* 1998). The maintenance of all habitats on Barrow Island is critical to the survival of burrowing bettongs (Barrow Island subspecies), as the species is distributed widely throughout the island and occupies all habitats (Short and Turner 1993).

The location of current and potential mainland and island reintroduction sites are illustrated in Figures 2 and 6. The importance of private conservation sites and those on pastoral leases should be emphasised, with the involvement of a broad spectrum of both Government and non-Government interests in the conservation of the western barred bandicoot, burrowing bettong and banded hare-wallaby, as outlined in the 'Affected interests' and 'Habitat critical to the survival of the species' sections. The common feature of all sites is the absence or control of introduced predators.

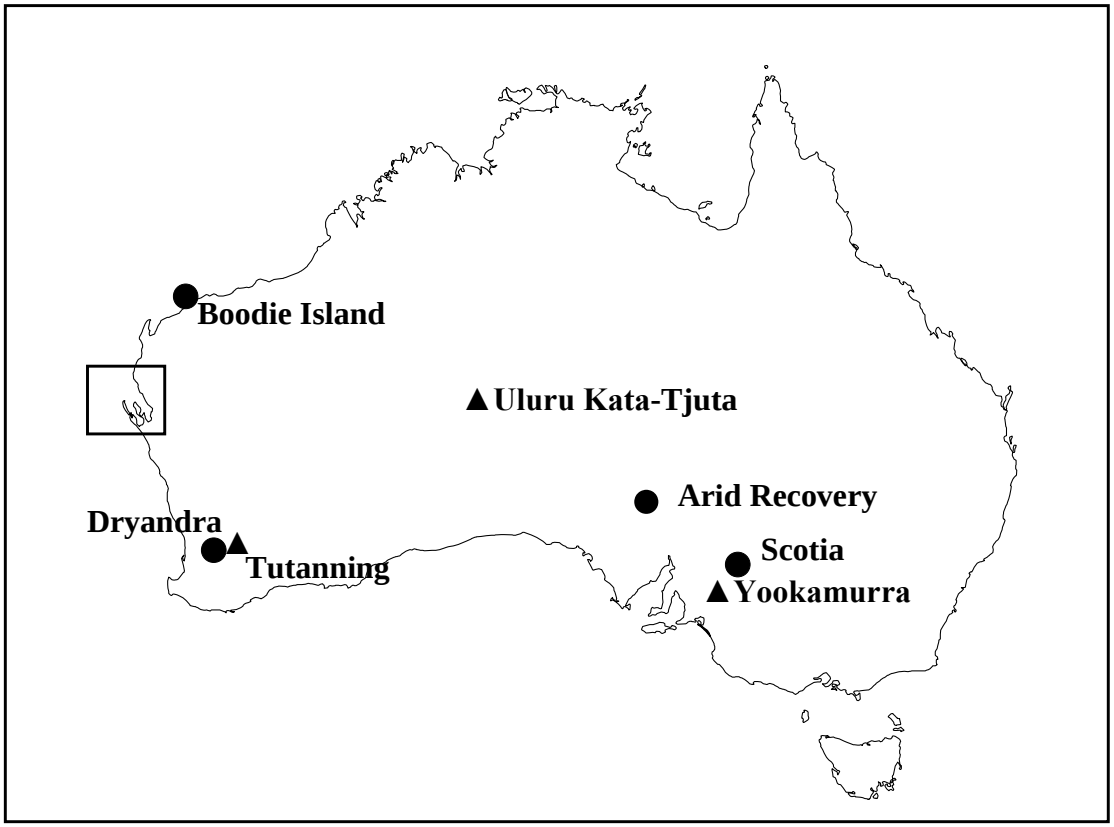

Figure 6: a) the location of current (●) and proposed (▲) reintroduction sites for the western barred bandicoot, burrowing bettong and banded hare-wallaby throughout Australia during the life of this Recovery Plan. Shark Bay sites are shown in detail in Figure 2 (Dirk Hartog Island, Heirisson Prong, François Peron National Park, Faure Island).

2.2 Important populations

The wild populations of the western barred bandicoot, burrowing bettong and banded hare-wallaby that reside on Bernier and Dorre Islands Class A Nature Reserve (Hancock *et al.* 2000) in Shark Bay have been identified as being of special significance in the long-term survival and recovery for these threatened marsupials. Bernier Island is approximately 44 km^2 and Dorre Island 53 km^2. The Shark Bay island populations represent the only remaining natural populations of the western barred bandicoot and banded hare-wallaby. The burrowing bettong is also found on Barrow and Boodie Island Class A Nature Reserves, which are similarly important repositories for remnant fauna that has been lost from mainland Australia.

Reintroduced populations of western barred bandicoots, burrowing bettongs and banded hare-wallabies (Table 1) are important as they have improved the conservation status of these three threatened species. Populations of western barred bandicoots, burrowing bettongs and banded hare-wallabies on Faure Island Wildlife Sanctuary are of particular importance due to the eradication of introduced predators and the low likelihood of re-invasion due to its island status.

Captive populations of the western barred bandicoot, burrowing bettong and banded hare-wallaby are important also, to provide animals for reintroduction programs (to supplement the use of animals from the wild populations) and for public education (Table 2). There is a dearth of sites with suitable habitat that are free from threatening processes to release animals. Animals are then held in captivity for extended periods, which is undesirable, from both genetic and behavioural perspectives. Current reintroduction sites that appear to be free from predators (Arid Recovery Reserve and Faure Island and Scotia Wildlife Sanctuaries) should be emphasised as sites for additional future translocations to strengthen the security of these three species.

Western barred bandicoot

The combined minimum population estimate for both Bernier and Dorre Islands is 2,200 – 4,400 (Short and Turner 1993) depending on conditions of drought or average rainfall respectively (Short and Turner 1993; Short *et al.* 1997a). The two island populations represent the only remaining wild populations of the species.

The Bernier Island animals are known to possess two diseases: a papilloma-like syndrome and chlamydiasis. The Dorre Island animals may be free from these two diseases, and if this is indeed the case, are of significantly greater importance as source animals for future translocations. However, due to the limited disease surveillance within the Bernier and Dorre Island populations, caution should be exercised in classifying any population as 'disease-free' (M. O'Hara[19] personal communication). The reintroduced populations at Heirisson Prong and Faure Island are also thought to be free from these two diseases, after examinations by Dr Colleen Sims from DEC in October 2002 and Murdoch University PhD students Lucy

[19] Dr Mandy O'Hara, Senior Lecturer in Pathology, School of Veterinary and Biomedical Science, Murdoch University

Woolford and Mark Bennett in October 2005. Due to the current disease status of Bernier Island animals, these three presumed 'disease-free' populations may represent the only available populations for future reintroductions. Conservation of these populations is therefore essential to the survival of the species. There have been no recent signs of disease at the Arid Recovery Reserve. This population may therefore be 'disease-free' also but considerable caution needs to be used when classifying the population as such and this will not be resolved until a screening test has been developed.

Burrowing bettong

There are estimated to be 1,600 - 4,300 burrowing bettongs on Bernier and Dorre Islands, depending on conditions of drought or average rainfall respectively (Short and Turner 1993; Short *et al.* 1997a). The two island populations represent two of four remaining wild populations of the species; the other two are at Boodie and Barrow Islands off the north-west coast of Western Australia, where there is estimated to be 3,400 burrowing bettongs on the 233 km^2 Barrow Island (Short and Turner 1993) and 200+ burrowing bettongs on Boodie Island (Morris 2002).

Reintroduced populations on Heirisson Prong, the Arid Recovery Reserve and Faure Island all appear to be doing well and are therefore of significant importance to the continued conservation efforts for burrowing bettongs.

Banded hare-wallaby

The combined Bernier and Dorre Island populations were estimated at 7,700 - 9,700, depending on conditions of drought or average rainfall respectively (Short and Turner 1993; Short *et al.* 1997a). The two island populations represent the only remaining wild populations of the species.

There were unsuccessful attempts to reintroduce banded hare-wallabies to Dirk Hartog Island in 1974, and the mainland at François Peron National Park in 2001. Both failed primarily due to cat predation. Conservation of the Bernier and Dorre Island populations is therefore essential to the survival of the species. Twenty nine banded hare-wallabies were reintroduced to Faure Island Wildlife Sanctuary in 2004, 2005 and 2006 by AWC and the population appears to be increasing, with an estimate of 40 animals on the island (A. Dugand[12] personal communication). A translocation of an additional ten animals is planned for 2007. The Faure Island population is likely to be of considerable importance in the future conservation of the species due to its island status and lack of introduced predators.

3. KNOWN AND POTENTIAL THREATS

3.1 Identification of threats

Western barred bandicoot

Finlayson (1961) attributed the demise of the western barred bandicoot from South Australia to predation by foxes. Maxwell *et al*. (1996) list predation by cats and foxes, modification of vegetation by rabbits and stock, and possibly changes in fire regimes in parts of its former range, as reasons for the decline to extinction of the western barred bandicoot on mainland Australia. Richards and Short (2003) and Richards (2004) regard predation by cats and foxes as the primary threat to the persistence of this species. They suggested that good quality habitat with dense cover may be an important factor in the success of mainland reintroductions where complete eradication of predators cannot be guaranteed. Areas of dense cover in more mesic areas of Western Australia and coastal Victoria, New South Wales and Queensland have probably contributed to the persistence of other species of bandicoot on mainland Australia. However, it is recommended that the species not be reintroduced to sites where introduced predators are present in the absence of intensive monitoring.

Burrowing bettong

Short (1998) and Short and Turner (2000) regarded predation by foxes and cats as the primary reason for the decline of the burrowing bettong on mainland Australia and the primary threat to the persistence of reintroduced mainland populations. They have not declined on Bernier, Dorre and Barrow Islands in recent times (Short and Turner 1993). Their potential vulnerability on their remaining island refuges is illustrated by the loss of bettongs from Dirk Hartog Island early this century and from Boodie Island in 1985. The former is thought to have been due to predation by feral cats, and the latter was due to a rat eradication program in 1984 that unintentionally eradicated the bettongs (Burbidge and George 1978; Short and Turner 1993; Maxwell *et al*. 1996; Short 1999a; Morris 2002). Severe drought can also affect populations. Raw spotlighting figures suggest a possible ~ 80% reduction in observations of this species between August 06 and April 07 on Bernier and Dorre Islands.

Reintroductions to the Gibson Desert in 1992 and to Yookamurra Sanctuary in South Australia in 1995, 1996, 2001 and 2004 were thought to have failed because of predation by feral cats (Christensen and Burrows 1994), and predation by cats and foxes (J. Bentley[7] personal communication) and possibly poor habitat quality (Short and Turner 2000), respectively. All future releases to Yookamurra have been postponed until the fence has been upgraded (J. Bentley[7] personal communication). A decline in burrowing bettong numbers on Heirisson Prong in 2002 – 2003 was attributed to predation by cats (J. Short unpublished data). Robley *et al.* (2002) and Short and Turner (2000) found that an abundance of European rabbits was not a limiting factor in the reintroduction of burrowing bettongs at Heirisson Prong.

Banded hare-wallaby

Short and Turner (1992) suggested that the decline of the banded hare-wallaby from the mainland was likely to be due to a combination of predation by feral cats and

habitat destruction. Their disappearance predated the arrival of the fox in Western Australia.

While there is some doubt that banded hare-wallabies occurred on Dirk Hartog Island (Baynes 1990), Shortridge (1909, p. 818) noted that "in the south of Dirk Hartog Island there is a large sheep station and the wallabies are said to have entirely left that end of the island". Their suggested extinction from the island around 1920 was thought to be due to predation by feral cats (Burbidge and George 1978), and an attempt to reintroduce (or introduce) the species in 1974 failed, probably due to a combination of predation by cats, a period of summer drought, and the impact of grazing by livestock (Short and Turner 1992).
Ride *et al.* (1962) and Tyndale-Biscoe (1973) have suggested that marked fluctuations in the population size of banded hare-wallabies over time may pose some threat to their persistence on Bernier and Dorre Islands. However, Short and Turner (1992) and Tyndale-Biscoe (2005) suggested that the apparent fluctuations in numbers over time might be largely an artefact of site of collection. They thought that their status was relatively secure provided that no exotic predators are introduced, due to their persistence on the islands for some 8,000 years and the consistency with which the species have been collected over the past 100 years.

Common threats

There appear to have been a common series of threats to the former mainland populations of the western barred bandicoot, burrowing bettong and banded hare-wallaby and many other threatened native mammal species, which include predation by the introduced fox and feral cat, habitat alteration by rabbits, livestock and clearing, and changes in fire regimes. Many of these threats remain on the mainland.

The major threats to the island populations of the western barred bandicoot, burrowing bettong and banded hare-wallaby and their habitats, outlined in the *Shark Bay Terrestrial Reserves Management Plan 2000-2009* (Hancock *et al.* 2000) and equally applicable to Barrow and Boodie Islands are:

- The introduction of exotic species, particularly foxes and feral cats, and also rabbits, rats, and mice;
- Disease;
- A major fire event;
- Inappropriate recreation activity or development;
- Inappropriate management practices, and
- Climate change, especially if combined with increased wildfires.

These threats are potentially of similar significance to the reintroduced populations, and disease and wildfire are significant threats to captive populations.

Introduced predators – the European fox and feral cat

The European fox may have been introduced to Australia as early as 1845 for hunting, but the wild population is thought to have originated from releases in Victoria in the 1870s (Rolls 1969). By 1930, the fox occurred throughout half of the continent (Jarman 1986), and within 100 years of its release, covered all of mainland Australia except the tropical north (Jarman 1986). The fox is a solitary hunter and opportunistic scavenger, with no specialised food requirements (Henry 1986; Saunders *et al.* 1995). Their diet consists typically of rabbits, sheep and kangaroo carrion, rats, mice, and

insects (Jarman 1986). They are noted for their surplus killing behaviour, killing prey at a rate greater than that necessary for food or food storage, with limited or no utilisation of the prey killed (Short *et al.* 2002). Foxes have been responsible for the surplus killing of native mammals such as the burrowing bettong (Short *et al.* 2002).

Foxes have long been recognised as a threat to native wildlife (e.g. Le Souef and Burrell 1926; Finlayson 1961); however, the extent of their impact was not widely accepted until recent studies such as those of Christensen (1978; 1980), Kinnear *et al.* (1988), Priddel (1989), Short and Turner (2000), Kinnear *et al.* (2002), and Short *et al.* (2002). They are now recognised as a primary threat to the success of mammal reintroductions on mainland Australia.

The history of the introduction of the feral cat to Australia is less well known than that of the fox. Burbidge *et al.* (1988) reported comments from Aborigines of the central deserts that cats have "always been present", suggesting that they may have arrived prior to European settlement. Burbidge *et al.* (1988) suggested that cats might have been introduced in the 1600s by Dutch shipwrecks, by Dutch, French or English explorers in the 200 years prior to European settlement, or even by Macassan traders from Indonesia commencing in the late eighteenth century. However, Gaynor (2000) found no evidence of cats carried on board Macassan praus, nor the arrival of cats in Western Australia prior to 1826.

Short (1999a) provided evidence that cats of British origin had become established in temperate Australia in the mid-nineteenth century. He suggested that cats may have been present in northern Australia prior to European settlement, but are less likely to have been present in southern Australia prior to settlement in 1788 due to a lack of records and a preponderance of the black colour morph associated with cats of British origin. After a comprehensive search of a variety of historical sources, Abbott (2002) found no evidence that the cat was present on the mainland prior to European settlement. He suggested that cats spread from multiple coastal introductions in the period 1824-1886, colonising the majority of the continent by 1890.

Cats hunt by sight and are accomplished "sit and wait predators" (Newsome 1995). The most common items found in their diet in Australia are rabbits, small mammals and reptiles (e.g. Dickman 1996; Risbey *et al.* 1999; Paltridge 2002). They consume a wide variety of native and introduced mammals, and have been found to consume bandicoots and bettongs when available (Dufty 1991; Christensen and Burrows 1994; Short and Turner 2000).

Flannery (2003) has suggested that cats may not have been responsible for the extinction of any species in the Australian environment, pointing out that cats coexist with native mammals on Kangaroo Island in South Australia and in Tasmania. However, Short and Turner (2000) and Richards and Short (2003) regarded both introduced foxes and feral cats as the primary threat to reintroduced burrowing bettongs and western barred bandicoots at Heirisson Prong in Shark Bay. A number of threatened mammal reintroductions have failed in the arid zone due primarily to predation by cats (e.g. Short *et al.* 1992; Gibson *et al.* 1994; Christensen and Burrows 1994; Southgate 1994; Morris *et al.* 2004; Hardman 2006). Burbidge and Manly (2002) found that the presence of both foxes and cats were correlated with the extinction of critical weight range mammals on Australian islands, but cats were associated with extinctions on the more arid islands only. Extinctions of mammals on

arid islands with cats but no foxes include Dirk Hartog, Hermite, Trimouille, St Francis and Reevesby Islands (Burbidge and Manly 2002). Both the reintroduced populations and the wild threatened mammal populations on Bernier, Dorre, Faure, Barrow and Boodie Islands are extremely vulnerable to the introduction of feral cats.

Introduced mammalian herbivores

Many studies have highlighted the detrimental impact of introduced herbivores (rabbits, sheep, cattle, horses, goats) on the Australian environment (e.g. Rolls 1969; Foran 1986; Payne *et al.* 1987; Friedel *et al.* 1990). Morton (1990) suggested that introduced herbivores, in particular the rabbit, played a significant role in the decline of mammals from the arid and semi-arid zone of Australia. He suggested that introduced herbivores had altered the vegetation so that refuge areas during periods of drought were no longer available. This habitat degradation, combined with the impact of introduced predators and changes in fire regimes in some areas, was thought to have increased the risk of local extinctions of native mammals.

Various authors (Finlayson 1958; Newsome 1971; Burbidge and McKenzie 1989) have attributed the extinction of the burrowing bettong from mainland Australia to competition by rabbits during periods of drought. However, Robley *et al.* (2002), Richards and Short (2003) and Richards (2004) have demonstrated that the impacts of rabbits on reintroduced populations of burrowing bettongs and western barred bandicoots at Heirisson Prong were minimal, and did not appear to affect the ability of these species to reproduce and establish a population at this site. Burrowing bettongs and rabbits coexisted with rabbits in the same warren for some time in South Australia (Copley *et al.* 2003). There is no information available about interactions between banded hare-wallabies and rabbits. Despite these observations, where possible, rabbits should be controlled or eradicated to facilitate recreating past habitats, and avoid the potential for interspecific competition.

Other introduced herbivores, including livestock (camels, goats, cattle, pigs, sheep and donkeys) have been implicated in widespread habitat alteration (Rolls 1969); however, their distributions are no longer sympatric, with the exception of the limited low density population of feral goats on Peron Peninsula.

Disease

Shortridge (1909) reported the "sudden and unaccountable" disappearance of a number of species of mammal by 1880, thought to be caused by "some epidemic or disease", which "appeared to be a kind of marasmus". Short (2004) suggested that the loss of mammals described by Shortridge may have been a result of a combination of predation by feral cats and disease born by cats or house mice. Richards and Short (1996) provided anecdotal evidence from an early resident of the Nullarbor, of some "strange virus" that had caused the extinction of the burrowing bettong prior to the arrival of foxes in the Nullarbor region. Burbidge *et al.* (1988) mentioned that there are no data to implicate disease in the extinction of Western Australian mammals. However, Abbott (submitted) collated historical evidence of the spread of epizootic disease from the Shark Bay region of Western Australia in 1880 to the lower south west before 1920, and thought that disease was a more plausible explanation than feral cats for the early decline of native mammal species in the western third of Australia prior to the establishment of rabbits and foxes.

The potential for the introduction of disease by humans within the threatened Shark Bay marsupial populations was listed as a threat by Hancock *et al.* (2000). In May 2000 symptoms of two diseases in the wild western barred bandicoot population on Bernier Island, and captive populations at Peron Peninsula, Kanyana, Dryandra Field Breeding Facility, Monarto Zoo and the Arid Recovery Reserve at Roxby Downs (though no signs have been evident in the released population) were discovered. Friend (2002) provided a summary of evidence and symptoms of the diseases and future management and research directions in his report on the *Workshop on Disease in Western Barred Bandicoot Populations* held at DEC's WA Wildlife Research Centre in July 2002.

One of the conditions is a papilloma-like syndrome, which progresses from wart-like growths to invasive carcinomas (M. O'Hara[19] personal communication). This disease has no effective treatment and has resulted in the death or euthanasia of over 20 animals from captive colonies at Kanyana and the Peron Captive Breeding Centre. The second involves ocular disease associated with isolation of *Chlamydia*, with animals showing a variety of symptoms including corneal opacity, conjunctivitis, ocular discharge, swollen eyelids and apparently ruptured eyeballs. Clinical symptoms were correlated with positive tests for four *Chlamydiales* types identified by gene sequencing (Warren *et al.* 2005). Investigation of wild populations on Bernier Island resulted in the discovery of a low level of positive *Chlamydia* (of several different types) in both ocular and urogenital samples, but not necessarily associated with clinical disease.

Sims (2002) suggested that the papilloma-like syndrome might have been introduced as a result of human activity on the islands, although recent examination of museum specimens only has identified the presence of the disease in Bernier Island animals since at least 1982 (S. Hill[20], personal communication). Actions from the workshops have resulted in the production of disease risk and hygiene guidelines for future trapping, translocation and captive breeding work in Western Australia (Chapman *et al.* 2005), diseased animals held in captivity or at reintroduction sites have been euthanased, the captive breeding colony at the Peron Captive Breeding Centre was closed, euthanased animals were collected for future research at Murdoch University, and all future translocations of the western barred bandicoot from diseased populations were placed on hold, pending further research into the papilloma-like syndrome. A symposium on western barred bandicoot research was held at Murdoch University in February 2007 to outline current conservation and research effort (Bennett 2007).

The extent of the threat of disease is unknown; however, diseases in native wildlife can contribute to poor population health, and reduced fertility. Extinctions caused by disease are often difficult to diagnose, as diseases do not usually leave conspicuous numbers of dead and dying animals (Caughley and Gunn 1996). There is currently no evidence that the papilloma-like syndrome is transmissible between native species other than in the western barred bandicoot. However, both diseases are thought to be of significant concern to the future conservation of the western barred bandicoot, and as such, should be considered in all future management of wild, reintroduced and

[20] Stephanie Hill, Technical Officer, DEC, Albany.

captive populations (Sims 2002). Ongoing research into aspects of the diseases is under way.

Toxoplasmosis is an infectious disease caused by the one-celled protozoan parasite *Toxoplasma gondii*. Cats are the only known definitive hosts of this parasite (Johnson *et al.* (1988), which is common in marsupials as both a subclinical infection and an overt disease (Munday 1978). For example, toxoplasmosis is prevalent in wild populations of eastern barred bandicoots (Obendorf and Munday 1990), and macropods in South Australia (Johnson *et al.* 1988). The disease has caused the death of western barred bandicoots in captivity at Kanyana Wildlife Rehabilitation Centre (J. Butcher, personal communication). Dickman (1996) suggested that declining populations of native wildlife should be screened to determine whether toxoplasmosis currently has serious deleterious effects. Research by Peter Adams from Murdoch University suggested that toxoplasmosis is not prevalent in the native mammal fauna of Shark Bay (P. Adams[21], personal communication).

Hardman (2006) found three endoparasite species (*Strongyloides* sp., *Entamoeba* sp. and *Eimeria* sp.) in banded hare-wallabies reintroduced to Peron Peninsula in winter and spring, though animals appeared free of the parasites during summer and autumn. No ectoparasites were found.

Fire

Bernier Island has no documented history of burning; however, substantial portions of Dorre Island were burnt in 1860, 1909 and 1973 (Ride *et al*. 1962; Hopkins and Harvey 1989; Hancock *et al.* 2000). Fires have therefore been infrequent in the last hundred years. Fire may substantially reduce population size in the short term, but in the long term, populations are likely to maintain their ability to recover, in a fashion similar to recovery from drought (Short *et al.* 1997a).

The Bernier and Dorre Islands Nature Reserve is not promoted for recreational use, and while day access is allowed, overnight camping is prohibited. It is designated a 'No Planned Burn Area', and management strategies are to prohibit all open/wood fires, facilitate early detection of fire through local community (predominantly fishermen) and agency communication, and, in the event of a fire, conduct immediate monitoring to assess whether suppression is warranted or feasible. Fire may play a significant role in reducing cover and exposing animals to predation, particularly banded hare-wallabies that rely on dense cover for shelter and are consumed by wedge-tailed eagles (Richards and Short 1998), and western barred bandicoots that rely on litter for the construction of nests.

Burbidge *et al.* (1988) suggested a possible link with the disappearance of critical weight range mammals from the central deserts and the timing of Aborigines departing from the region, resulting in a change in fire regimes (as described in the 'Habitat critical to the survival of the species' section above). However, the persistence of banded hare-wallabies on Bernier and Dorre Islands, with their very different fire histories, the infrequent nature of fire in the region, and the lack of

[21] Peter Adams, PhD student, Murdoch University.

introduced predators, suggests that a fire mosaic is not important on islands (Short and Turner 1992; I. Abbott[22] personal communication).

Due to the infrequent nature of fires within the Shark Bay region, future fire management should continue to minimise the risk of fire, both on Bernier and Dorre Island, and at reintroduction sites within that region (François Peron National Park, Heirisson Prong and Faure Island). Fire is more of an issue at sites such as Dryandra Woodland and Scotia Wildlife Sanctuary; however, DEC and AWC have implemented fire management regimes in these areas.

Inappropriate recreational activities, development, or management practices

The threat of inappropriate recreational activities, development, or management practices on either the wild or reintroduced populations of the western barred bandicoot, burrowing bettong and banded hare-wallaby is minimised under current management guidelines outlined in the *Shark Bay Terrestrial Reserves Management Plan 2000 – 2009* (Hancock *et al.* 2000), *Western Shield – Bringing Back our Wildlife* (Burbidge *et al.* 1995), *Western Shield Fauna Recovery Program – Strategic Plan July 1999 to June 2004* (CALM 1999b), *Dryandra Woodland Management Plan 1995 – 2005* (Friend *et al.* 1995), *Barrow Island Nature Reserve Interim Management Guidelines* (CALM 1999a), the *Draft Environmental Impact Statement/Environmental Review and Management Programme for the Proposed Gorgon Development* (Chevron Australia 2005), *The 1996 Action Plan for Australian Marsupials and Monotremes* (Maxwell *et al.* 1996), the *Heirisson Prong Community Biosphere Reserve Shark Bay, Western Australia Management Plan 1999 – 2004* (Short 1999b) and the *Faure Island Pastoral Lease Management Plan* (Australian Wildlife Conservancy 2002b). Recreational and tourism activities tend to be permitted and managed in the Shark Bay region in a "manner compatible with conservation and other goals," to minimise environmental impact (Hancock *et al.* 2000, p. 39) but this doesn't stop fishermen and day trippers from lighting fires on the beaches which potentially could get out of control. Recreational activities such as fishing, camping and picnicking are permitted on Heirisson Prong (Short 1999b), where western barred bandicoots and burrowing bettongs have been reintroduced.

Hancock *et al.* (2000) regarded any permanent structures such as island-based tourism facilities (e.g. jetties, airstrips, accommodation) as incompatible with the high conservation values of Bernier and Dorre Islands. Barrow Island has a history of industrial development, with the establishment of an oilfield in 1964 by West Australian Petroleum Limited. Development is continuing with the recent proposed expansion by Chevron and Joint Venturers (Gorgon Development). While subject to a rigorous Environmental Management System and Quarantine Risk and Management Strategy (Chevron Australia 2005), this minimises, but does not preclude, detrimental effects upon native mammals and their habitat, particularly introduction of exotic species such as the black rat *Rattus rattus* and house mouse *Mus musculus*.

Developments at reintroduction sites such as François Peron National Park may be compatible with community participation, ecotourism and public education where appropriate actions are taken to minimise environmental impacts. A successful example is 'Barna Mia', a native animal viewing enclosure that has been constructed

[22] Dr Ian Abbott, Research Fellow, DEC, Perth.

at Dryandra Woodland by DEC, where the general public are able to see western barred bandicoots, burrowing bettongs and banded hare-wallabies.

3.2 Populations under threat

The Bernier and Dorre Island populations are the only two extant populations of western barred bandicoots and banded hare-wallabies, and two of four extant populations of the burrowing bettong; Barrow and Boodie Islands are the others. Conservation of the three remnant wild populations is essential to the survival of these species.

While reintroduced populations of western barred bandicoots and burrowing bettongs have been established in fenced areas on the mainland at Heirisson Prong and the Arid Recovery Reserve, reintroduced burrowing bettongs have been lost from the Gibson Desert, Dryandra Woodland and Yookamurra Wildlife Sanctuary, and banded hare-wallabies have been lost at François Peron National Park. The long-term security of the mainland populations is uncertain due to the inability to ensure effective control of introduced predators. Yookamurra, Heirisson Prong, François Peron National Park, and Dryandra Woodland all have a history of intermittent fox and cat incursions despite intensive management. The Arid Recovery Reserve and Scotia Wildlife Sanctuary have avoided fox incursions. Reintroduced populations at Faure and Boodie Islands are potentially more secure due to the lack of introduced predators and lower chance of invasion. Continuity of management and the provision of resources in perpetuity are important considerations in the long-term viability of any reintroduced population.

4. RECOVERY OBJECTIVES AND CRITERIA

4.1 Prior conservation measures

Recovery Team and recovery planning

A Recovery Team for the western barred bandicoot, burrowing bettong and banded hare-wallaby was established in late 2004 by CALM (now DEC), to coordinate conservation actions for these species. The inaugural meeting was held in February 2005. Much of the information contained within this Recovery Plan has been collated through past recovery actions, the *Report on Threatened Shark Bay Marsupials* (Richards 2003), Recovery Team meetings and the assistance of numerous people involved in the conservation of Australia's threatened mammals.

Monitoring of wild populations

Long-term monitoring of the western barred bandicoot and burrowing bettong populations on Dorre Island was typically carried out on an annual basis (and on occasion more frequently) using established trapping grids at White Beach on Dorre Island by CALM (now DEC) from 1986 to 1988, and 1992 to 2000 (Richards 2003). CSIRO conducted comprehensive spotlighting and trapping surveys of Bernier, Dorre and Barrow Islands in 1988 and 1989, and repeated these three years later at Bernier and Dorre Islands (Short *et al.* 1998; Short and Turner 1999). The only systematic monitoring of banded hare-wallabies has been by CSIRO. Other monitoring of the banded hare-wallaby populations has typically been sporadic and ad hoc, conducted opportunistically by hand netting, and was detailed in Richards *et al.* (2001). On the whole, monitoring of the wild populations of the different species on the different islands has tended to be sporadic and ad hoc. There has been no long-term, consistent and cohesive approach to regular monitoring of all of these species on the two islands, though the combination of CALM and CSIRO trapping has provided key information about the threatened mammal populations.

Reintroduction

As outlined in Tables 1 and 2, a number of captive and reintroduced populations have been established for the western barred bandicoot, burrowing bettong and banded hare-wallaby in Western Australia, South Australia and New South Wales.

The Heirisson Prong Community Biosphere Reserve was established in 1989, with the support of the local Useless Loop community and mining company Shark Bay Salt Joint Venture (SBSJV). Introduced predators were removed from the fenced 12 km^2 reserve. Burrowing bettongs were reintroduced from Dorre Island to Heirisson Prong between 1992 and 1995 (in three separate releases) by CSIRO and the Useless Loop Community Biosphere Project Group (ULCBPG) (Short *et al.* 1994; Short and Turner 2000). Western barred bandicoots were reintroduced from Dorre Island in 1995 by CSIRO and the ULCBPG (Richards and Short 2003).

The burrowing bettong population was established on the 1,200-hectare peninsula, and a subset of animals was housed within an eight-hectare predator-free refuge between 1992 and 1998 (Short and Turner 2000). The population reached a peak of over 350 animals in 2000, with over 1,000 known recruits to the population. By 2004

the population had declined to ten individuals due to the cumulative impact of fox and cat incursions, but had recovered by the end of 2006 to over 50 individuals. These dramatic population fluctuations highlight the vulnerability of mainland populations where fence maintenance cannot be guaranteed, and question the use of Heirisson Prong animals as a source for future translocations due to the history of population bottlenecks and subsequent low genetic diversity.

The western barred bandicoot population was established within a 17-hectare predator-free refuge and animals were then released to free-range in 1997 on the 1,200-hectare peninsula. The population has fluctuated substantially, reaching over 100 animals in 1999 (population estimate of 130; Richards and Short 2003), declining to nine within the predator-free refuge by 2001 due to the impact of feral cats, and then increasing to >500 by May 2006 (J. Short unpublished data) with the removal of feral cats in 2003, clearly demonstrating the species' vulnerability to feral cat predation.

DEC's *Project Eden* was launched in 1994. Successful fox baiting of the 1,050 km^2 Peron Peninsula was implemented in 1995 and feral cat control in 1996. Populations of malleefowl were established in 1997 and greater bilbies in 2000. Woylies were reintroduced between 1997 and 2000. The woylie population has persisted but remains low and its long-term viability under current levels of cat predation pressure is uncertain (Morris *et al.* 2004). Banded and rufous hare-wallabies were reintroduced in 2001 but did not survive (Hardman 2006). Quenda were also reintroduced in 2006. Plans to reintroduce a range of threatened mammals at the site have been modified (Mawson 2004; Morris *et al.* 2004).

The Arid Recovery Project (ARP) was commenced in 1997, with the construction of a 14 km^2 fenced area and the removal of all rabbits, cats and foxes (Arid Recovery Project 2002). Burrowing bettongs were reintroduced from Heirisson Prong in 1999 and from Bernier Island in 2000, followed by western barred bandicoots from Bernier Island in 2001. Western barred bandicoots and burrowing bettongs were housed initially in an eight-hectare release pen, and were then released to the 14 km^2 conservation area in 2002 (Arid Recovery Project 2002). The reserve was increased to 60 km^2 and rabbits, cats and foxes eradicated from this larger area in 2001. Numbers of animals trapped in 2005 were 277 bettongs and 35 bandicoots (K. Moseby[11] personal communication). Greater stick-nest rats and greater bilbies were reintroduced in 1999 and 2000 respectively. The reserve has since been expanded to 86 km^2 in 2005, with a reduced height fence, providing a unique area to allow research into feral animal control methods and dispersal mechanisms for the reintroduced mammals.

AWC acquired the Faure Island pastoral lease in 1999. The island is managed for conservation, though a small flock of sheep has been retained in confined paddocks and graze an infestation of buffel grass *Cenchrus ciliatus* around the homestead. Over 1,500 feral goats have been culled or removed and a single individual remains (Richards 2007). Feral cats were eradicated from the island in 2001 by DEC (Algar *et al.* 2001; Algar and Burrows 2004), making this the third largest island in the world where feral cats have been successfully eradicated (Nogales *et al.* 2004). A workshop was held by AWC in collaboration with DEC in the same year to consider the native mammal species most suitable for translocation to Faure Island. This recommended

the translocation of a suite of five threatened mammals, mostly from Bernier and Dorre Islands. Burrowing bettongs from Heirisson Prong, and Shark Bay mice from Bernier Island (via the Perth Zoo captive breeding colony) were reintroduced to Faure Island in 2002 (Parsons *et al.* 2002a), and both species are well-established, with over 260 burrowing bettongs and over 100 Shark Bay mice captured throughout the island during the annual monitoring in July 2006 (A. Dugand[12], personal communication). Banded hare-wallabies were reintroduced from the Peron Captive Breeding Centre in 2004, 2005 and 2006 and the population now numbers >40 individuals.

AWC also acquired Scotia and Yookamurra Sanctuaries in New South Wales and South Australia in 2002 from Earth Sanctuaries Ltd. After improving the perimeter fence around a 4,000-hectare section of Scotia Wildlife Sanctuary, AWC reintroduced burrowing bettongs, using animals from Yookamurra Wildlife Sanctuary, on four separate occasions in December 2004, and February, June and September 2005, as part of a multi-species reintroduction of the burrowing bettong, woylie, bridled nailtail wallaby *Onychogalea fraenata* and greater bilby. Burrowing bettongs have established well at the site (J. Bentley[7] personal communication). Reintroductions of burrowing bettongs at Yookamurra Wildlife Sanctuary between 1995 and 2004 by Earth Sanctuaries Ltd. and AWC failed due to cat and fox predation and poor predator-proof fencing (J. Bentley[7] personal communication). The perimeter fence is to be upgraded, and burrowing bettongs released into the 1,100-hectare enclosure at a later date.

Burrowing bettongs from Barrow Island were translocated to Boodie Island in 1998 by DEC, after their eradication during a rat baiting campaign (Morris 2002). The population quickly established, with an estimate of over 200 animals in 2000 (K. Morris[5] personal communication). The island is free from introduced predators.

Burrowing bettongs were released to Dryandra Woodland by DEC on two separate occasions in spring 2003 and autumn 2004. Both failed due to predation by foxes and wedge-tailed eagles. This occurred despite the area being regularly baited for foxes since 1982 in association with DEC's *Western Shield* initiative (Friend and Beecham 2004; N. Thomas[3] personal communication). Burrowing bettongs were also released to the Gibson Desert Nature Reserve by DEC in 1992, but the reintroduction failed due to predation by feral cats (Christensen and Burrows 1994).

A cross-cultural workshop was held at Yulara in September 1999 entitled *Biodiversity and the Re-introduction of Native Fauna at Uluṟu - Kata Tjuṯa National Park* (Gillen 1999) to identify and discuss the issues surrounding the re-establishment of locally extinct fauna within the Uluṟu - Kata Tjuṯa National Park. The burrowing bettong was identified as one of the potential species for reintroduction. A project leader for the *Uluṟu - Kata Tjuṯa National Park Species Reintroduction Project* was employed in late 2002, and a project team consisting of Parks Australia staff was subsequently organised. A second meeting was held in February 2003 between the project team, the Biodiversity Conservation unit of NRETA staff and private consultants. Decisions were made to construct a feral-proof enclosure at Uluṟu, based upon the design of the 'Mala Paddock' enclosure at Watarrka National Park, with advice from the ARP and AWC regarding fence design (Liddle 2004). The 170-hectare enclosure was completed at the beginning of September 2005 and the rufous hare-wallaby was reintroduced at the end of September 2005, with the involvement of Aṉangu, the

Mutijulu community, Green Corps, and staff from Parks Australia. The project is unique, in that it serves the dual purposes of the conservation of both natural and cultural heritage.

Captive breeding

Captive breeding populations have been established at a range of sites, with current populations outlined in Table 2. Kanyana Wildlife Rehabilitation Centre have housed western barred bandicoots from Bernier and Dorre Islands since 1994 in small enclosures, managed by June and Lloyd Butcher, with support from DEC (Vance 2002), though only a handful of animals remain for research purposes. DEC's Peron Captive Breeding Centre housed and successfully bred western barred bandicoots in 3 m x 2 m enclosures from 1998 to 2005, and has maintained a breeding population of banded hare-wallabies in 8 m x 12 m enclosures with natural vegetation since 1998 (Morris *et al*. 2004). The Dryandra Field Breeding Facility was established at Dryandra Woodland in 1997, which involved the construction of two ten-hectare captive breeding enclosures of natural vegetation. The western barred bandicoot, burrowing bettong and banded hare-wallaby were introduced in 1998 (Friend and Beecham 2004). Significant losses of banded hare-wallabies to predation by wedge-tailed eagles have occurred and, despite restocking in 2004 after improvements in the provision of cover to protect against avian predators, a single banded hare-wallaby remains (Friend and Beecham 2004; N. Thomas[3] personal communication).

The remaining western barred bandicoots held at the Peron Captive Breeding Centre were transferred to the Kanyana Wildlife Rehabilitation Centre in 2005 where the animals have been held for further investigation into the two disease entities (the papilloma-like syndrome and *Chlamydia*) (J. Butcher[21] personal communication). The papilloma-like syndrome was also found in a single individual within the captive population at Dryandra as recently as 2006.

CSIRO (and now the ULCBPG and SBSJV) maintained a 17-hectare predator-free enclosure at Heirisson Prong that currently houses western barred bandicoots. Captive breeding within the predator-free refuge for the western barred bandicoot was discontinued in 1999 and for the burrowing bettong in 1998, when populations of the two species were regarded as established on the greater 12 km^2 Heirisson Prong peninsula (Richards and Short 2003; Short and Turner 2000); however, both were reinstated in 2000 and 2003, respectively, due to feral cat predation within the conservation area.

Captive populations of burrowing bettongs are currently held in smaller four-hectare compounds at the AWC's Yookamurra Wildlife Sanctuary.

Threat abatement

Two workshops on *Disease in Western Barred Bandicoot Populations* were hosted by DEC at the WA Wildlife Research Centre in July 2002 and July 2003, after the discovery of symptoms of two diseases in wild and captive populations led to concerns regarding the conservation of this species and others (Friend 2002). The diseases and their associated symptoms and histological structure were described by Dr Mandy O'Hara from Murdoch University. Quarantine and disease management procedures were also outlined for the Peron Captive Breeding Centre, Kanyana and

Return to Dryandra Field Breeding Facility populations. The results of a trip to Bernier and Dorre Islands to screen for the presence of the diseases were examined, and discussions were held to formulate future plans of action. Recovery Team meetings hosted by DEC in February 2005 and February 2007, and a Western Barred Bandicoot Symposium hosted by Murdoch University in February 2007 (Bennett 2007) furthered discussions on actions related to disease management and research. As a consequence, western barred bandicoot breeding ceased at the Peron Captive Breeding Centre in 2005, with all surviving animals transferred to Kanyana Wildlife Rehabilitation Centre and carcasses stored at Murdoch University for future research.

Fox baiting techniques have been established by DEC in Western Australia with significant success. Under the *Western Shield* initiative, three species of native mammals have been removed from the threatened species list and many populations of threatened mammal have recovered or been reintroduced in their former ranges (McNamara 2004; Possingham *et al.* 2004).

A number of studies on the control of feral cats have been undertaken by DEC, CSIRO and the ARP, including trials of methods of trapping, the use of a variety of baits and lures, and poisoning (Algar and Sinagra 1996; Risbey *et al.* 1997; Short *et al.* 1997b; Short *et al.* 2002; Arid Recovery Project 2002; Algar *et al.* 2002; Algar and Burrows 2004). In particular, DEC has developed kangaroo sausage baits for feral cats, impregnated with 1080 that have shown considerable signs of success in controlling cat numbers (Algar and Burrows 2004). CSIRO had some success in controlling cats using mouse carcasses impregnated with 1080 poisoned 'one-shot oats' (Short *et al.* 1997b). Both methods worked well when applied in late autumn when prey abundance (rabbits) was low. Improvements in the design of barrier fences over time have also led to increased success in maintaining mainland areas free from predator incursions.

Successful cat control has been achieved on some islands (Burbidge and Manly 2002) especially where prey species are absent or limited. However, the successful broadscale application of cat control methods in the arid and semi-arid zones of the mainland has so far met with varied success. For example, an aerial baiting trial of DEC's kangaroo sausage baits was carried out in 2002 in a buffer zone surrounding the ARP at 5% bait intensity used by DEC. Track transects indicated a 100% decrease in cat activity after the baiting; however, re-invasion was rapid and by three months post-baiting, there was no difference between control and baited track transects (Arid Recovery Project 2002). Similarly, Morris *et al.* (2004) reported an 80% reduction in cat numbers at François Peron National Park in 2002; however, the remaining number of cats was regarded as too high to consider the reintroduction of 'cat-vulnerable' species such as western barred bandicoots and banded hare-wallabies. In contrast, malleefowl and greater bilbies have been successfully established at Peron Peninsula despite the resident cat population, suggesting that these species are less vulnerable to cat predation. The future success of mainland reintroductions of a range of species such as those reintroduced at Heirisson Prong, Peron Peninsula and Dryandra Woodland are dependent on the development of more effective methods of cat control. Until that time, exclusion fencing remains a key strategy for protection of mainland populations of threatened mammals.

Community involvement, education and knowledge transfer

Strong and ongoing community participation in the Heirisson Prong project resulted in the ULCBPG and partners winning the 2001 Gold Banksia Award for Environmental Achievement and the 2001 Banksia Award for Community Group Achievement. Community members manage the day-to-day running of the conservation reserve, including predator control, maintenance of the predator-proof barrier fence, track maintenance and monitoring of predator incursions. They participate also in the monitoring of reintroduced western barred bandicoots and burrowing bettongs.

The Friends of the ARP are an active group who contribute to the management and research objectives of the ARP by coordinating volunteer involvement in the project, fundraising and conducting working bees (Arid Recovery Project 2002). They have shared in a number of awards, including the National Australia Bank Community Link Award in 2002 and one of the Prime Minister's Awards for Excellence in Community Business Partnerships in 2003. The ARP is dedicated to raising public awareness about arid zone conservation. A viewing platform and hide, and interpretive signage have been constructed at the Arid Recovery Reserve.

The *Project Eden* Community Advisory Committee was established with the inception of *Project Eden*, but the group has remained dormant for some time. However, *Project Eden* has been extremely active in community education through the regular involvement of local schools in reintroduction activities, school presentations and fundraising support, public talks and hands on presentations of threatened species during school holiday activities, as well as annual teacher professional development programs in recent years. Annual Landscope Expeditions, TAFE field training and Bushranger cadets programs have also been a regular feature of the Project, as well as dozens of individual volunteer and work experience placements, including long-term arrangements for credited internship placements with several tertiary Conservation and Biology degree programs.

AWC have strong community support, and conservation programs are funded through public donations. Volunteer programs are well-established and education programs are established at some AWC properties.

Kanyana Wildlife Rehabilitation Centre relies heavily on volunteer support to manage the facility.

Scientific papers detailing the biology, distribution and abundance of each species on Bernier, Dorre and Barrow Islands have been published by Short *et al*. (1997a, 1998), Short and Turner (1992, 1993, 1999), and Richards *et al.* (2001). Reintroductions of burrowing bettongs to the Gibson Desert and Heirisson Prong in Western Australia have been documented by Christensen and Burrows (1994), and Short and Turner (2000) respectively. The reintroduction of the western barred bandicoot to Heirisson Prong has been documented by Richards and Short (2003). Reintroductions of burrowing bettongs and western barred bandicoots to the Arid Recovery Reserve in South Australia were reported by the Arid Recovery Project (2001; 2002) and Arid Recovery (2004), and reintroduction of banded hare-wallabies to Francois Peron National Park was reported by Morris *et al.* (2004), Hardman (2006), and Hardman and Moro (2006). Details of the diet and population ecology of the burrowing bettong

at Heirisson Prong was published by Robley (1999) and Robley *et al.* (2001, 2002), and of social structure by Sander *et al.* (1997). Friend (1990) reported on the status of the western barred bandicoot in Western Australia, and Visser (2000) analysed their diet at Heirisson Prong.

Population viability analysis

A population viability analysis was undertaken by Richards (2004) as part of a PhD thesis, to examine future options for the recovery of the western barred bandicoot. "Populations were modeled under a variety of scenarios to examine the possible effects of changes in carrying capacity, founder population size, inbreeding depression, and the occurrence of drought and cat predation as catastrophes, on the probability of population extinction. The analysis highlighted the need for eradication of feral cats, above all other management actions" (Richards 2004, p. iii).

Other

DEC have completed a disease risk management strategy, *Minimising Disease Risk in Wildlife Management* (Chapman *et al.* 2005), that is pertinent to future research and management of the threatened mammal fauna of Bernier, Dorre, Faure, Barrow and Boodie Islands. The document presents "standard operating procedures to minimise the risk of disease transmission between wildlife populations and from wildlife to DEC personnel and their families" (Chapman *et al.* 2005, p. 1). The disease risk management strategy is to be incorporated into future translocation proposals and management documents associated with the Bernier and Dorre Island Nature Reserves and other island reserves. It does not, however, address the issue of possible spread of disease by members of the public visiting Bernier and Dorre Islands.

DEC conducted hybridisation trials of western barred bandicoots from Bernier and Dorre Islands at Kanyana between 1994 and 1997, with fertile F1 offspring produced (Friend and Beecham 2004).

PhD student Steve Smith from Griffith University in Queensland has conducted a genetic study of wild and reintroduced populations of the western barred bandicoot in relation to disease expression. Preliminary microsatellite and mitochondrial DNA analysis has revealed extremely low levels of genetic diversity in the wild Bernier and Dorre Island populations that are amongst the lowest ever recorded for marsupials (S. Smith[23] personal communication). The reintroduced Heirisson Prong population has a similar level of genetic diversity to the source population (from Dorre Island), whereas the Dryandra Field Breeding Facility population exhibited a level of microsatellite diversity almost twice that of either of the founder populations (hybridised from Bernier and Dorre Islands) as a result of crossbreeding. However, this hybridisation of western barred bandicoots from the two islands did not appear to result in an increase in the diversity of mitochondrial DNA (S. Smith[24] personal communication).

The genetics of burrowing bettongs is currently being studied by PhD student Felicity Donaldson from the University of Western Australia in conjunction with AWC. She has collected samples from wild populations on Bernier, Dorre and Barrow Islands,

[23] Steve Smith, PhD student, Griffith University, Queensland.

and reintroduced populations on Heirisson Prong and Faure Island, for mitochondrial DNA analysis.

Recent DNA work done on banded hare-wallabies by Westerman et al (2002), has confirmed the unique taxonomic status of this species, although Prideux may have questioned this again in 2004. Work has also been done on sperm morphology and DNA of banded hare-wallabies by Dr Steve Johnstone at the University of QLD. The complete mitochondrial genome of banded hare-wallabies was mapped by Nilson (2006).

4.2 Recovery objectives and performance criteria

This Recovery Plan guides the recovery of the threatened western barred bandicoot, burrowing bettong and banded hare-wallaby, for five years, from 2007 to 2011 inclusive.

Overall Recovery Objectives

The overall recovery objectives of this report are to undertake conservation actions which:

1. **Ensure the survival and improve the status of the Shark Bay island subspecies of the western barred bandicoot (currently 'Endangered' under the EPBC Act and the *IUCN Red List 2000*) within 20 years to a level that will enable downlisting to 'Vulnerable', based on the IUCN (1994) criteria of extent of occurrence.**
2. **Ensure the survival and maintain the status (currently 'Vulnerable' under the EPBC Act and the *IUCN Red List 2000*) of the Bernier and Dorre Island subspecies of the burrowing bettong and banded hare-wallaby and Barrow Island subspecies of the burrowing bettong.**

The western barred bandicoot meets the IUCN (2001) Red List of Threatened Species Criteria B1 + 2ac; the population is known to exist at no more than five locations and extreme fluctuations in extent of occurrence may occur. The burrowing bettong and banded hare-wallaby meet the 2001 IUCN Red List of Threatened Species Criteria D2; the population is characterised by an acute restriction in the number of locations (typically less than five).

The downgrading of the status of these three species to anything less threatened than 'Vulnerable' is unlikely within the next five years, due to the inability to implement broadscale control of the primary threat of introduced predators on mainland Australia.

There are five primary strategies recognised for the recovery of the western barred bandicoot, burrowing bettong and banded hare-wallaby:

1. Maintenance of wild populations;
2. captive breeding;
3. threat abatement;
4. reintroduction; and

5. community involvement and education.

Specific Recovery Objectives

The specific objectives of this report are achievable within the next five years, and contribute to the overall objectives relating to the conservation of the western barred bandicoot, burrowing bettong and banded hare-wallaby. These are to:

1. **Protect the wild populations and their habitat;**
2. **Maintain captive populations;**
3. **Investigate the disease status of captive and wild western barred bandicoot populations, and develop a strategy for disease control;**
4. **Maintain existing reintroduced populations;**
5. **Reintroduce western barred bandicoots, burrowing bettongs and banded hare-wallabies to mainland and island sites;**
6. **Review the taxonomic status and genetic structure of the three species;**
7. **Use population viability analysis (PVA) to compare the viability of wild and current and potential reintroduced populations;**
8. **Enhance community participation and education;**
9. **Secure ongoing funding for the implementation of the Recovery Plan; and**
10. **Enhance linkages between projects involved in the recovery of western barred bandicoots, burrowing bettongs and banded hare-wallabies.**

For each recovery action, performance evaluation is regarded as the responsibility of the primary organisation involved in that recovery action, and the Recovery Team.

5. RECOVERY ACTIONS

The Recovery Team for the western barred bandicoot, burrowing bettong and banded hare-wallaby is currently managed by DEC. An annual meeting to review the progress of the Recovery Plan and modify recovery actions where necessary is organised by DEC, with participation from DEC, AWC, ARP, ULCBPG, DEH and other organisations as appropriate.

5.1 Protect the wild populations and their habitat

5.1.1 Manage Bernier and Dorre Islands Nature Reserve for the conservation of the western barred bandicoot, burrowing bettong and banded hare-wallaby.

The Bernier and Dorre Island populations of the western barred bandicoot, burrowing bettong and banded hare-wallaby have long been recognised to be of extreme conservation importance and are vital to the persistence of the species (Hancock *et al.* 2000). Maintenance of the existing wild populations on Bernier and Dorre Islands are key objectives and actions outlined in the *Shark Bay Terrestrial Reserves Management Plan* (Hancock *et al.* 2000), the *1996 Action Plan for Australian Monotremes and Marsupials* (Maxwell *et al.* 1996), the *Report on Threatened Shark Bay Marsupials* (Richards 2003) and the *Rufous Hare-wallaby Recovery Plan* (Richards 2005).

Bernier Island is maintained as a day-use area only, with no overnight camping permitted. Dorre Island is currently a prohibited access area but this may be opened up for day use as outlined in the Shark Bay Terrestrial Reserves Management Plan (Hancock *et al.* 2000). The islands require protection from the introduction of exotic animals (the populations are extremely vulnerable to the introduction of foxes and feral cats), and frequent and/or extensive fires. A disease risk management strategy has been produced by DEC (Chapman *et al.* 2005).

Responsibility: DEC
Cost: $28,000 per year
Priority: High
Completion date: Ongoing

5.1.2 Develop and implement a cost-effective monitoring program for the wild Bernier and Dorre Island populations.

Cost-effective sampling programs should be designed and implemented for Bernier and Dorre Islands where monitoring has typically varied, yet is recognised as critical to the conservation of the western barred bandicoot, burrowing bettong and banded hare-wallaby. It had been recommended that monitoring of the three species be carried out every three years (Short 1995; Maxwell *et al.* 1996; Friend and Orell 1997). In light of the incidence of disease in the western barred bandicoot population on Bernier Island, and the recent lack of both bandicoot captures and sighting of tracks in one area of Bernier Island in July 2005 (F. Donaldson[1] personal communication), there is additional focus on the importance of regular monitoring, particularly for this species.

DEC chaired a workshop to discuss future monitoring regimes for the threatened mammals on Bernier and Dorre Islands in July 2003, with participants from DEC, CSIRO and AWC. A consensus was reached that regular monitoring was important. The collation and evaluation of past monitoring regimes will assist in establishing a monitoring baseline.

An effective monitoring protocol should include checking for signs of disease (particularly examining western barred bandicoots for evidence of the papilloma-like syndrome and ocular disease) and condition, determination of 'early warning' thresholds of population declines that may be cause for concern, and the development of management actions should such an occasion arise (K. Morris[5] personal communication). Should there be evidence of population declines for any of these species, and for any reason (e.g. disease in western barred bandicoots), then the islands should not be utilised further as a source for reintroductions until populations recover. The regular and long-term monitoring of the island populations is necessary to determine whether populations are declining, or simply fluctuating in abundance with varying environmental conditions.

At present, it is recommended that the procedures used by Short and Turner (1992) on Bernier Island in 1989 and 1992, and on Dorre Island in 1988 and 1991 (spotlight transects) should be used to standardise future monitoring (Short 1995; Langford 2001; Richards 2005; K. Morris[5] personal communication). Monitoring every year is preferred, especially for the western barred bandicoot until the impact of the disease entities on the Bernier Island population is better understood. An annual report is needed to DEC and the Recovery Team to facilitate adaptive management of the populations and their habitat.

Responsibility: DEC
Cost: $49,060 Year 1, $49,060 Year 2, $51,513 Year 3, $54,088 Year 4, $56,793 Year 5
Priority: High
Completion date: Ongoing

5.1.3 Manage Barrow Island Nature Reserve for the conservation of the burrowing bettong.

Barrow Island has long been recognised as an important asset to the conservation estate of Western Australia, being classified as a Class A Nature Reserve in 1910. Petroleum exploration and production activities began in the mid-1960s, and through cooperative environmental management practices developed initially by West Australian Petroleum Limited (WAPET) and more recently by Chevron, and DEC, the conservation values of the island have remained protected. The current Gorgon Joint Venturers have adopted a risk-based approach to Quarantine Management on Barrow Island due to an increased risk of introduction of exotic species through the proposed Gorgon development (Chevron Australia 2005). This environmental management plan complements the *Barrow Island Nature Reserve Interim Management Guidelines* (CALM 1999a), with the aim of continuing to protect the population of burrowing bettongs, and the integrity of other native fauna and flora and their island habitat. Chevron has committed significant funds to cover environmental management issues on Barrow Island.

Responsibility: DEC, Chevron
Cost: $6,000 per year
Priority: High
Completion date: Ongoing

5.1.4 Continue the mammal monitoring program for the wild Barrow Island burrowing bettong population.

Regular monitoring of the Barrow Island Nature Reserve mammal fauna has been conducted by DEC since 1998, in conjunction with Chevron (and formerly WAPET), by annual trapping. This monitoring program will continue, with an extra component provided as part of an increase in quarantine procedures due to the proposed Gorgon Development, and funded by Chevron.

Responsibility: DEC, Chevron
Cost: $28,000 per year
Priority: High
Completion date: Ongoing

5.2 Maintain captive populations

Captive breeding of burrowing bettongs employing minimal husbandry has been very successful at Heirisson Prong, Dryandra Field Breeding Facility, and Yookamurra and Scotia Wildlife Sanctuaries, and extensive breeding of western barred bandicoots has also been successful at Heirisson Prong (Table 2). More intensive captive breeding of western barred bandicoots at Peron Captive Breeding Centre and Kanyana Wildlife Rehabilitation Centre has met with a lesser degree of success due to lower than expected productivity, overcrowding (due to postponed releases) and disease (Morris *et al.* 2004). Mawson (2004) regarded banded hare-wallabies as potentially unsuitable for extensive pen systems (e.g. Dryandra Field Breeding Facility) due to the risk of avian predation (Friend and Beecham 2004), while intensive pen systems were more successful (e.g. Peron Captive Breeding Centre) but associated with a much higher cost of production. With the establishment of a number of populations of western barred bandicoots, burrowing bettongs and banded hare-wallabies on islands and within extensive fenced areas, the need for captive breeding for future stocking of reintroduction sites may be reduced. Resources may then be best directed to managing reintroduction sites.

5.2.1 Maintain the captive populations at the Dryandra Field Breeding Facility.

The population of the burrowing bettong at the Dryandra Field Breeding Facility is to be maintained for use as a source population for future reintroductions in Western Australia. The high productivity of the bettong populations means that bettongs need to be harvested from the enclosure for release elsewhere on a regular basis to prevent overcrowding. However, due to the recent expression of the papilloma-like syndrome within the western barred bandicoot population and low recruitment, no bandicoots should be transferred from or to the facility until it is deemed ‘disease-free’, which may take up to four years from the removal of the last diseased animal in 2006.

Responsibility: DEC
Cost: $25,000 per year

Priority: High
Completion date: Ongoing

5.2.2 Maintain the captive banded hare-wallaby population at the Peron Captive Breeding Centre.

The population of banded hare-wallabies at the Peron Captive Breeding Centre is to be maintained as a source population for future reintroductions in Western Australia, particularly to Dirk Hartog and Faure Islands in Shark Bay.

Responsibility: DEC
Cost: $60,000 per year
Priority: High
Completion date: Ongoing

5.3 Investigate the disease status of captive and wild western barred bandicoot populations and develop a strategy for disease control

5.3.1 Determine which populations of western barred bandicoot are free from the papilloma-like syndrome.

At present, the only populations regarded as 'disease-free' are those on Dorre Island, Heirisson Prong and Faure Island. Incidences of disease have been found in western barred bandicoots at all other locations, particularly Bernier Island and the Dryandra Field Breeding Facility. There have been no signs of disease in the Arid Recovery Reserve population; however, some of the original source animals from Bernier Island, which were housed in isolation at Monarto Zoo in South Australia, were diseased. These animals were not released.

The 'disease-free' populations require monitoring once per year for a minimum of four years to support the 'disease-free' status. Health checks of all animals captured during subsequent regular monitoring should be performed. A field guide for diagnosing symptoms of the papilloma-like syndrome should be produced to assist in field determination of the disease, and distributed to all stakeholders involved in the conservation of the western barred bandicoot. In addition, the development of a diagnostic test to discriminate between subclinical cases of the disease and unaffected bandicoots would be beneficial.

'Disease-free' populations only are to be used for translocation to reintroduction sites. In addition, the use of animals from Dorre Island as a source for translocations should be minimised, particularly if there is any firm evidence of disease, if drought conditions prevail, or there are signs that the population size has declined.

Responsibility: Murdoch University, DEC
Cost: $208,000
Priority: High
Completion date: 2009

5.3.2 Research into the western barred bandicoot papilloma-like syndrome.

An investigation to identify the cause of the papilloma-like syndrome is underway at Murdoch University. Veterinary Pathologist Dr Mandy O'Hara, has examined tissue

samples from 25 diseased western barred bandicoots, and described a variety of wart-like lesions and carcinomas. Some of the research questions include:

- Investigation of the aetiology of the disease;
- Pathogenesis and epidemiology of the disease;
- Host specificity; and
- Significance of infections to the reproduction and dynamics of the infected western barred bandicoot populations.

Two PhD students (Lucy Woolford and Mark Bennett, under the supervision of Mandy O'Hara) are currently working on this project. Future plans for the research include:

- The development of skin cell lines from bandicoots to attempt to transmit and characterise the disease in cell culture;
- The collection of fresh wart and tumour samples to attempt disease transmission into nude mice;
- Test existing wart and tumour samples with a range of primers developed from conserved sequences within papilloma and polyoma viruses;
- Continue with the microscopic, electron microscopic and immunohistochemical examination of wart and tumour samples;
- Characterise the epidemiology of the wart syndrome;
- Develop a diagnostic test for subclinical cases of the wart syndrome (provided the disease has an infectious cause); and
- Collect samples for collaborators to investigate the presence of *Chlamydophila* spp. and characterise the immune status of the western barred bandicoot (M. O'Hara[19] personal communication).

Additional samples are required to fully document the disease occurrence within wild and captive populations. Research outcomes will assist in producing methods for disease control in captive and reintroduced populations.

Responsibility: Murdoch University
Cost: $582,000
Priority: High
Completion date: 2009

5.3.3 Research into the incidence, abundance and impact of *Chlamydia* and toxoplasmosis in captive and wild populations.

Information on the incidence, abundance and impact of *Chlamydia* and toxoplasmosis on the western barred bandicoot, burrowing bettong and banded hare-wallaby is to be acquired, further to research published by Warren *et al.* (2005). Evidence of *Chlamydia* in the western barred bandicoot and toxoplasmosis in a number of native mammal species (Munday 1978; Obendorf and Munday 1990; P. Adams[22] personal communication), suggests the need to further investigate the risk associated with these two diseases in native mammal populations. Some research into toxoplasmosis has been completed by Murdoch University PhD student Peter Adams. DEC Veterinarian and *Project Eden* Coordinator Dr Colleen Sims, has investigated the incidence of *Chlamydia* in western barred bandicoots on Dorre and Bernier Islands.

Responsibility: DEC, Murdoch University

Cost: $45,000
Priority: High
Completion date: 2009

5.4 Maintain existing reintroduced populations

While western barred bandicoots, burrowing bettongs and banded hare-wallabies have all been reintroduced to mainland and island sites (Table 1), the future persistence of extant populations remains uncertain due to threats from introduced predators and disease. Control methods for foxes have led to broadscale success of reintroductions in the south-west of Western Australia; however, the control of feral cats, particularly in the semi-arid and arid zones remains problematic. The recent observations of disease in the western barred bandicoot are of considerable concern, particularly in considering future translocations and ensuring that animals are 'disease-free'.

5.4.1 Maintain the reintroduced populations of western barred bandicoots and burrowing bettongs at Heirisson Prong, Shark Bay, Western Australia.

The burrowing bettong was reintroduced to Heirisson Prong in 1992 and the western barred bandicoot in 1995. These populations have been extant for 14 and 11 years respectively, and have provided animals for translocation to the Arid Recovery Reserve and Faure Island. The peninsula must be maintained free from foxes and feral cats to ensure the continued persistence of both species. The reintroduced populations of western barred bandicoots and burrowing bettongs were monitored four times per annum from 1992 through to 2004; however, current monitoring has decreased to biannually, with the removal of support for the project by CSIRO in July 2005. Dramatic population fluctuations due to predator incursions have led to the supplementation of the current burrowing bettong population with the return of 17 animals transferred to Faure Island in 2002. This occurred in October 2005.

The western barred bandicoot population is presumed "disease-free". Examinations of >20 animals by DEC Veterinarian Colleen Sims in October 2002 and by Murdoch University PhD students Lucy Woolford and Mark Bennett in October 2005 found no evidence of the papilloma-like syndrome.

The 1996 Action Plan for Australian Monotremes and Marsupials (Maxwell *et al.* 1996) recommended securing Heirisson Prong as conservation estate, to assist the prospects for long-term support for the project and populations of threatened mammals. The *Heirisson Prong Community Biosphere Reserve Management Plan 1999-2004* (Short 1999b) lists recommendations specific to the management of Heirisson Prong and its populations of reintroduced western barred bandicoots and burrowing bettongs, including securing the long-term tenure of Heirisson Prong as a conservation area and maintaining the area free of domestic and feral cats. An upgrade of the predator-proof fence with funds from Natural Heritage Trust (NHT) greatly improved the security of this site. DEC has been approached to assist with cat management by aerial baiting in the buffer zone to the south of the predator-proof fence. These two management enhancements would make a significant improvement to the long-term security of this conservation site. However, the risk of predator incursions and low genetic diversity due to past population bottlenecks remains. If

the populations are to continue to be managed over the next five years and beyond, they would benefit from additional animals sourced from Dorre Island to increase genetic diversity. In the event of the cessation of support for this project by SBSJV, steps will be taken to remove as many animals as possible for translocation to alternative sites determined by DEC. Associated costs of the translocations will be met by CSIRO for a maximum period of 12 months.

Responsibility: ULCBPG, SBSJV, Wildlife Research and Management
Cost: $50,000 per year
Priority: High
Completion date: Ongoing

5.4.2 Maintain the reintroduced populations of western barred bandicoots and burrowing bettongs at the Arid Recovery Project (ARP), Roxby Downs, South Australia.

The burrowing bettong was reintroduced to the Arid Recovery Reserve in 1999 and the western barred bandicoot in 2001. The Arid Recovery Reserve has been maintained free from foxes, feral cats and rabbits. The reintroduced populations of western barred bandicoots and burrowing bettongs are monitored biannually by trapping, and more regularly by track transects. The populations are self-sustaining, requiring no further translocations; however, an additional reintroduction of western barred bandicoots would supplement the small founder size.

Responsibility: ARP
Cost: $30,000 per year
Priority: High
Completion date: Ongoing

5.4.3 Maintain the reintroduced populations of western barred bandicoots, burrowing bettongs and banded hare-wallabies at Faure Island, Shark Bay, Western Australia.

The burrowing bettong was reintroduced to Faure Island in 2002. The population had grown rapidly from a founder size of 17 animals to at least 260 by July 2006, and is self-sustaining, requiring no further translocations. The banded hare-wallaby was reintroduced in 2004, 2005 and 2006, and has since expanded in number and distribution. A further translocation of ten animals is scheduled for May 2007. Twenty western barred bandicoots were reintroduced from Heirisson Prong in October 2005. The populations are monitored at least biannually.

The *Faure Island Pastoral Lease Management Plan* (Australian Wildlife Conservancy 2002b) lists general aims, strategies and actions to guide the management of Faure Island and its translocated mammals, including detailing the impact of threatening processes on Faure Island, implementing sheep stocking rates conducive to nature conservation, and eradicating goats. Under current management regimes, the island should become an important refuge for threatened mammals. Faure Island should provide a more secure site for the conservation of the western barred bandicoot, burrowing bettong and banded hare-wallaby due to its island status, free from introduced predators. The populations may become available for translocation to other sites, but are limited genetically and would benefit from supplementation with additional animals from the Shark Bay islands.

Responsibility: AWC
Cost: $55,000 per year
Priority: High
Completion date: Ongoing

5.4.4 Maintain the reintroduced burrowing bettong population at Scotia Wildlife Sanctuary.

The burrowing bettong was reintroduced to Scotia Wildlife Sanctuary on four separate occasions in 2004 and 2005, with 30 animals translocated at a time (120 in total). It is hoped that a self-sustaining population will be established within two years of their translocation and within five years of Recovery Plan adoption, requiring no additional translocations. University of Sydney PhD student, Graeme Finlayson, has been closely monitoring the reintroductions.

Responsibility: AWC
Cost: $25,000 per year
Priority: High
Completion date: Ongoing

5.4.5 Maintain the reintroduced burrowing bettong population at Boodie Island.

The burrowing bettong was reintroduced to Boodie Island in 1993 by DEC (Morris 2002). The population of over 200 animals is regarded as self-sustaining and requires minimal monitoring once every five years (K. Morris[5] personal communication).

Responsibility: DEC
Cost: $30,000 per year
Priority: Medium
Completion date: Ongoing

5.5 Reintroduce western barred bandicoots, burrowing bettongs and banded hare-wallabies to additional mainland and island sites

5.5.1 Assess the abundance and diet of feral cats on Dirk Hartog Island, Shark Bay, as a precursor to cat eradication efforts and mammal reintroductions.

Prior to the commencement of any conservation activities on Dirk Hartog Island in Shark Bay, the land tenure is to be changed from pastoral lease to conservation estate (eventually national park). The status of feral cats and goats on Dirk Hartog Island will be examined by detailed survey of the island, and control efforts are to be instigated to eradicate all feral cats and goats, following the methods successfully utilised by DEC on Hermite Island in the Montebello Islands (Algar *et al.* 2002), and DEC and AWC on Faure Island (Algar *et al.* 2001). The control strategy for feral cats on the island will involve a baiting campaign followed by a trapping program if warranted. Monitoring cat abundance and distribution before and after the baiting campaign will enable the success of the baiting campaign to be determined and indicate the need and location for further control activities. Reintroduction of the western barred bandicoot, burrowing bettong and banded hare-wallaby will then be conducted (beyond the life of this Recovery Plan).

Responsibility: DEC
Cost: $85,000
Priority: High
Completion date: 2009

5.5.2 Reintroduce burrowing bettongs to Dryandra Woodland.

Burrowing bettongs were reintroduced on two occasions from Dryandra Field Breeding Facility to Dryandra Woodland in spring 2003 and autumn 2004, as recommended by Friend *et al.* (1995) and Thomas *et al.* (2003). Both translocations failed predominantly due to predation by foxes and wedge-tailed eagles, despite an intensive monthly and ongoing regional fox control program associated with DEC's *Western Shield* initiative (N. Thomas[3] personal communication).

An additional reintroduction of burrowing bettongs is planned for spring 2007 after being housed in soft-release enclosures since November 2006. Animals will be released into the central section of Dryandra Woodland on the lateritic, loamy soils of the uplands that previously reintroduced animals appear to have preferred, and in more dense vegetation with artificial burrows, which will reduce the likelihood of wedge-tail eagle predation (N. Thomas[3] personal communication). Should this third release fail, it has been recommended that no further reintroductions take place unless remedial action is taken to overcome the factors responsible for the translocations' failure.

Responsibility: DEC
Cost: $25,000 per annum
Priority: Medium
Completion date: 2010

5.5.3 Reintroduce burrowing bettongs at Yookamurra Wildlife Sanctuary.

Burrowing bettongs have been reintroduced unsuccessfully to Yookamurra Wildlife Sanctuary on two occasions. AWC are planning to upgrade the perimeter fence in 2007/8 to ensure that it is predator-proof. Once this is achieved, it is hoped that a self-sustaining population of burrowing bettongs will be established in the 1,100-hectare enclosure within two years of their translocation and within five years of Recovery Plan adoption, requiring no additional translocations. The reintroduced population will be monitored every three months for the first six months, and then at least annually thereafter. Should this third release fail it is recommended that no further reintroductions take place unless remedial action is taken to overcome the factors responsible for the translocations' failure.

Responsibility: AWC
Cost: $30,000 Year 1, $20,000 Year 2, $10,000 Years 3 – 5 per annum
Priority: Low
Completion date: Ongoing

5.5.4 Establish a sustainable population of burrowing bettongs at Uluṟu-Kata Tjuṯa National Park.

A new purpose-built 170-hectare enclosure at Uluṟu-Kata Tjuṯa National Park, managed by Parks Australia and in close proximity to the Cultural Centre, was

completed in September 2005. The enclosure is surrounded by a four-metre firebreak free of vegetation, and the external perimeter is burnt at a distance of up to 100 m from the fence line to minimise fire risk. The release of rufous hare-wallabies (mainland subspecies) took place in September 2005 (Richards 2007), and a release of burrowing bettongs is planned to follow, hopefully in 2007/8 (E. Lee[24] personal communication). The enclosure is maintained as fox, cat and dingo-free. The population of burrowing bettongs will be monitored at least biannually, and where appropriate, genetic diversity will be maximised by the exchange of breeding animals with other captive populations.

Responsibility: Parks Australia
Cost: $45,000 Year 1, then $15,000 per year
Priority: Medium
Completion date: Ongoing

5.5.5 Reintroduce western barred bandicoots, burrowing bettongs and banded hare-wallabies to additional mainland sites.

Western barred bandicoots, burrowing bettongs and banded hare-wallabies may be reintroduced to additional mainland sites, provided foxes and feral cats are adequately controlled in these areas. Possible sites for one or more of these species include Lorna Glen, Dryandra Woodland and Mt Gibson Wildlife Sanctuary in Western Australia, and Scotia Wildlife Sanctuary in New South Wales. Animals may be sourced from captive breeding centres or other reintroduction sites such as Heirisson Prong, Arid Recovery Reserve or Faure Island. The reintroduced populations should be self-sustaining within three years of the first translocation, and will require regular monitoring.

Responsibility: DEC and others
Cost: Unknown
Priority: Medium
Completion date: Ongoing

5.6 Review the taxonomic status and genetic structure of western barred bandicoots and burrowing bettongs and BHW

Genetic studies were proposed to assist in determining the subspecific status and relationships of geographically separate and reintroduced (bottlenecked) populations of western barred bandicoots, burrowing bettongs and banded hare-wallabies (Friend and Orell 1997). This in turn will provide additional information on which to base future decisions about the use of source populations for reintroductions, the potential for hybridisation and exchange of animals between reintroduced populations, and the potential impact of small founder sizes of reintroduced populations. Genetic studies may utilise chromosomal differences, allozyme electrophoresis, mitochondrial or microsatellite DNA techniques, or alternatively, cross-breeding experiments.

[24] Emma Lee, Manager, Natural and Cultural Resources Unit, Uluru - Kata Tjuta National Park, NT.

5.6.1 Assess strategies for hybridisation of reintroduced populations to enhance genetic diversity.

Hybridisation of reintroduced populations of western barred bandicoots, burrowing bettongs and banded hare-wallabies should be considered if the Bernier, Dorre and Barrow Island populations are genetically similar, or if combined genetic diversity is increased, without compromising local adaptation. An evaluation of the benefits and ethics of hybridisation needs to be made by DEC and additional stakeholders, prior to further implementation of hybridisation, as suggested by Spencer and Moro (2001).

Western barred bandicoots from Bernier and Dorre Islands have been hybridised by DEC and maintained at the Dryandra Field Breeding Facility. Burrowing bettongs from the two Shark Bay islands have been reintroduced at the Arid Recovery Reserve and Yookamurra, setting a precedent for future hybridisation at other sites. University of Western Australia PhD student Felicity Donaldson is examining the level of genetic divergence between Bernier and Dorre Island burrowing bettongs, to determine whether hybridisation of the two populations is acceptable.

Responsibility: DEC, Recovery Team
Cost: $8,000
Priority: Medium
Completion date: 2009

5.6.2 Research into the taxonomic status and genetic structure of burrowing bettong populations from Barrow, Bernier and Dorre Islands.

Maxwell *et al.* (1996) recommended clarification of the genetics of the burrowing bettong; in particular the taxonomic relationship of the Bernier and Dorre Island populations with the Barrow Island population. Felicity Donaldson from the University of Western Australia, with support from AWC and DEC, is currently undertaking postgraduate research on the taxonomy of extant populations of the burrowing bettong. The results of her genetic analyses should clarify the acceptability of separation at the subspecific level of the Shark Bay island burrowing bettong populations from the Barrow Island population. She is also examining the genetic impact of bottlenecks on reintroduced populations on Faure and Boodie Islands.

Responsibility: UWA, DEC, AWC
Cost: $18,000 Year 1, $8,000 Year 2
Priority: Low
Completion date: 2008

5.6.3 Research into the taxonomic status and genetic structure of western barred bandicoot populations from Bernier and Dorre Islands, Heirisson Prong, Dryandra Field Breeding Facility and the Arid Recovery Reserve.

Steve Smith from Griffith University in Queensland is completing postgraduate research on the genetics of wild and reintroduced populations of the western barred bandicoot in relation to disease expression. The results of his genetic analyses should clarify the acceptability of a single extant subspecies, and provide evidence of the effect of severe bottlenecks on genetic diversity. The next stage of his research focuses on examining genetic variation that is directly related to immune response, fitness and adaptive potential, with the aim of determining the vulnerability of the western barred bandicoot to disease (S. Smith[24] personal communication).

Responsibility: Griffith University, DEC
Cost: $22,000 Year 1, $5,500 Year 2
Priority: Low
Completion date: 2008

5.7 Use population viability analysis (PVA) to compare the viability of wild and current and potential reintroduced populations

The use of population viability analysis (PVA) as a tool to assist in predicting the persistence of both wild and reintroduced populations may be beneficial to the recovery process. PVA provides a technique for modelling the chance of extinction or persistence of a population within a time frame into the future (Possingham and Davies 1995). Processes within small populations are unpredictable; therefore, the fate of populations can be modelled, based on simulated probability distributions (Lacy 1993). By adjusting parameters within the model (such as founder population size, reserve size, frequency of predation event) and choosing the best result, it has the potential to be used as a management tool in the field of conservation biology, and may assist in determining the suitability of potential reintroduction sites for western barred bandicoots, burrowing bettongs and banded hare-wallabies.

PVA modelling using VORTEX has been conducted by Richards (2004). This model may be advanced as a conservation tool to assess the comparative viability of wild and reintroduced (at current and potential sites) populations of the western barred bandicoot and to investigate ways of enhancing the long-term viability of populations under various scenarios (e.g. different reserve size, management regimes). Similar methodology may be employed to conduct PVA modelling for the burrowing bettong and banded hare-wallaby.

Responsibility: DEC
Cost: $5,000 Year 1, $2,500 Year 2
Priority: High
Completion date: 2009

5.8 Enhance community participation and education in the recovery of western barred bandicoots, burrowing bettongs and banded hare-wallabies

5.8.1 Continue involvement of the Useless Loop community in the management of Heirisson Prong, and the conservation of its populations of western barred bandicoots and burrowing bettongs.

Heirisson Prong has been home to reintroduced populations of the burrowing bettong since 1992 and western barred bandicoot since 1995. The conservation site is managed by the local community (Useless Loop Community Biosphere Project Group Inc. (ULCBPG)), with financial and infrastructure support from the mining company Shark Bay Salt Joint Venture (SBSJV). CSIRO supported research at the site from 1989 to 2005, and assisted with management and advice; however, they no longer

participate in the project. Wildlife Research and Management are continuing to monitor the western barred bandicoot and burrowing bettong populations, and offer advice to the ULCBPG.

The local community maintains a 2.8 km predator-proof barrier fence, conducts monthly ground baiting for fox control, liaises with DEC regarding the organisation of an annual aerial baiting for foxes and cats, and conducts trapping for feral cats in the area surrounding the conservation site. The continuity of this management, particularly predator control, is important for the long-term security of the threatened mammal populations. Hence, community involvement and ownership of the project and its achievements is encouraged.

Responsibility: ULCBPG, SBSJV, Wildlife Research and Management
Cost: $2,500 per year
Priority: High
Completion date: Ongoing

5.8.2 Continue community involvement in the Arid Recovery Project and the conservation of its populations of western barred bandicoots and burrowing bettongs.

The Arid Recovery Project (ARP) has housed reintroduced populations of the burrowing bettong since 1999 and western barred bandicoot since 2001. The Friends of Arid Recovery was established in 1998 and is involved in the project, producing a quarterly newsletter, coordinating volunteer involvement, staffing information displays, applying for funding, organising fundraisers and conducting working bees at the Arid Recovery Reserve. Friends of Arid Recovery also assists with fauna and flora monitoring and management of the Reserve. There is a display focusing on the achievements of the ARP and the reintroduced mammals. ARP have hosted Earthwatch Institute expeditions since 2003, with volunteers assisting with research at the Reserve, and support a number of university students, from the University of Adelaide, and through the International Student Volunteer program (Arid Recovery 2004).

Responsibility: ARP, Friends of the ARP, BHP Billiton
Cost: $2,500 per year
Priority: High
Completion date: Ongoing

5.8.3 Support tourism at Dryandra Woodland through public education and visits to Barna Mia.

Barna Mia is a four-hectare animal viewing enclosure located within Dryandra Woodland. It was constructed by DEC in 2002, with some support from the Regional Tourism Development Program (Sprigg 2004), and houses the western barred bandicoot, burrowing bettong, banded hare-wallaby and other species of threatened mammal. The enclosure attracts up to 2,500 visitors per year. Some 28 different schools and 300 school children also visited the facility in the 2004/05 financial year (T. Sprigg[25] personal communication). The primary role of Barna Mia is education, allowing the general public, school and university students to observe threatened

[25] Tricia Sprigg, DEC Narrogin.

native marsupials in a natural setting (Sprigg 2004). DEC work with the Dryandra Country Visitor Centre and Lions Club to promote Barna Mia.

Responsibility: DEC
Cost: $6,000 per year
Priority: Medium
Completion date: Ongoing

5.8.4 Support involvement of the Denham community in the management of *Project Eden.*

Specific recommendations of the *Shark Bay Terrestrial Reserves Management Plan* (Hancock *et al.* 2000) include promoting public awareness of the fauna by providing information, interpretation and education, and encouraging communication with the public, particularly the local community, to increase awareness of fauna conservation programs and values. The re-establishment of the *Project Eden* Community Advisory Committee or some similar community conservation group would assist in accomplishing this aim, by maintaining the regular community and school education and interaction activities, continuing TAFE and tertiary work placements and maintaining research collaborations and individual work experience programs.

Responsibility: DEC, WWF, TSN
Cost: $2,500 per year
Priority: Low
Completion date: Ongoing

5.8.5 Support limited ecotourism in the Shark Bay region in conjunction with *Project Eden*.

Ecotourism opportunities at François Peron National Park may be developed with no detrimental impacts on the reintroduced mammal populations or their habitat. A World Heritage Interpretation Centre was constructed in Denham, Shark Bay in 2006, to enable visitors to learn more about the area and to appreciate its distinctive values. The feasibility of establishing a tourism facility at François Peron National Park, similar to Barna Mia at Dryandra Woodland, to allow viewing of threatened mammals by the community and tourists may be investigated.
Responsibility: DEC, Shire of Shark Bay
Cost: $100,000 for 1 year to do feasibility study.
Priority: Low
Completion date: Ongoing

5.9 Secure ongoing funding for the implementation of the national Recovery Plan for the western barred bandicoot, burrowing bettong and banded hare-wallaby.

5.9.1 Organise Recovery Team meetings.

Recovery Team meetings are to be held at least biannually, with representatives from DEC, AWC, ARP, ULCBPG, DEWHA, WWF/TSN, and other stakeholders as appropriate. Minutes of the meetings will be circulated to participants and stakeholders within two weeks of each meeting.

Responsibility: DEC
Cost: $5,000 per year
Priority: High
Completion date: Ongoing

5.9.2 Source additional funding to support recovery actions for the western barred bandicoot, burrowing bettong and banded hare-wallaby.

Many recovery actions described above are funded, at least in part, by in-kind contributions such as salaries, infrastructure, vehicles and capital works. However, there is insufficient funding to cover all recovery actions, thus the development of funding applications submitted to appropriate funding bodies to implement recovery actions should be encouraged. Recovery Team members and stakeholders are able to pursue funding opportunities, with the guidance of the Recovery Team.

Responsibility: Recovery Team, DEC, ARP, ULCBPG, AWC
Cost: $3,000 per year
Priority: High
Completion date: Ongoing

5.10 Enhance linkages between projects involved in the recovery of western barred bandicoots, burrowing bettongs and banded hare-wallabies.

Emphasis has been placed upon increasing communication between stakeholders in the Shark Bay region, particularly to enhance linkages between DEC, ULCBPG and AWC (Richards 2003). Recovery Team meetings provide a good avenue for updates on each project and knowledge exchange. Site visits to Heirisson Prong, *Project Eden*, and Faure Island Wildlife Sanctuary also provide a means of exchanging information. Enhancing linkages between all projects involved in the conservation of the western barred bandicoot, burrowing bettong and banded hare-wallaby will facilitate the exchange of knowledge and experiences derived from reintroduction projects throughout Australia, and may achieve more efficient resource use.

Responsibility: Recovery Team, DEC, AWC, ULCBPG, ARP
Cost: $3,000 per year
Priority: High
Completion date: Ongoing

6. TOOLS TO ASSIST IMPLEMENTATION

6.1 Estimated costs of the recovery program

The recovery program is currently supported by the input of staff and resources from DEC, AWC, SBSJV, ULCBPG, ARP and Chevron.

Estimated costs of recovery actions for the first three years have been calculated at 2007 prices. Cost estimates include the salary component not met by stakeholders (other than DEH) and operating costs. Actions undertaken as normal operations by state agency staff have not been costed. Potential sources of additional funding include NHT Envirofund, Lotterywest and private or corporate sponsors.

6.2 Implementation table

Action	Description	3 Year Cost $	5 Year Cost $	Responsibility	Completion Date
5.1	**Protect existing wild populations and habitat**				
5.1.1	Bernier and Dorre Island management	84,000	140,000	DEC	Ongoing
5.1.2	Monitor Bernier and Dorre Island populations	149,633	260,514	DEC	Ongoing
5.1.3	Barrow Island management	18,000	32,000	DEC Chevron	Ongoing
5.1.4	Monitor Barrow Island population	84,000	140,000	DEC Chevron	Ongoing
5.2	**Maintain captive populations**				
5.2.1	Maintain Return to Dryandra Field Breeding Facility	75,000	125,000	DEC	Ongoing
5.2.2	Maintain Peron Captive Breeding Centre	180,000	300,000	DEC	Ongoing
5.3	**Western barred bandicoot disease status and control**				
5.3.1	Disease-free populations	208,000	208,000	Murdoch DEC	2009
5.3.2	Research papilloma-like syndrome	582,000	582,000	Murdoch	2009
5.3.3	*Chlamydia* and toxoplasmosis research	45,000	45,000	DEC Murdoch	2009
5.4	**Maintain reintroduced populations**				
5.4.1	Maintain Heirisson Prong populations	150,000	250,000	ULCBPG SBSJV	Ongoing
5.4.2	Maintain ARP populations	90,000	150,000	ARP	Ongoing
5.4.3	Maintain Faure Island populations	165,000	275,000	AWC	Ongoing
5.4.4	Maintain Scotia bettong population	75,000	125,000	AWC	Ongoing
5.4.5	Maintain Boodie Island bettong population	90,000	150,000	DEC	Ongoing
5.5	**Reintroduce to mainland and island sites**				
5.5.1	Dirk Hartog Island feral cat	85,000	85,000	DEC	2009

Action	Description research	3 Year Cost $	5 Year Cost $	Responsibility	Completion Date
5.5.2	Reintroduce bettongs to Dryandra	75,000	100,000	DEC	2010
5.5.3	Reintroduce bettongs to Yookamurra	60,000	80,000	AWC	Ongoing
5.5.4	Establish Uluru Kata-Tjuta National Park bettong population	60,000	90,000	Parks Australia	Ongoing
5.5.5	Reintroductions to other mainland sites			DEC Others	Ongoing
5.6	**Taxonomic and genetic research**				
5.6.1	Hybridisation strategies	8,000	8,000	DEC	2009
5.6.2	Taxonomic status of burrowing bettongs	26,000	26,000	UWA DEC	2008
5.6.3	Western barred bandicoot genetics	27,500	27,500	Griffith University	2008
5.7	**PVA modelling**	**7,500**	**7,500**	**DEC**	**2009**
5.8	**Enhance community participation and education**				
5.8.1	Useless Loop community participation	7,500	12,500	ULCBPG SBSJV WR&M	Ongoing
5.8.2	ARP community participation	7,500	12,500	ARP Friends of ARP BHP	Ongoing
5.8.3	Dryandra community participation	18,000	30,000	DEC	Ongoing
5.8.4	Denham community participation	7,500	12,500	DEC WWF/TSN	Ongoing
5.8.5	*Project Eden*/Faure Island ecotourism	7,500	12,500	DEC Shark Bay Shire	Ongoing
5.9	**Secure ongoing funding**				
5.9.1	Recovery Team meetings	15,000	25,000	DEC	Ongoing
5.9.2	Source additional funding	9,000	15,000	Recovery Team DEC ARP ULCBPG AWC	Ongoing
5.10	**Australia-wide interagency linkages**	**9,000**	**15,000**	**Recovery Team DEC AWC ULCBPG ARP**	**Ongoing**
TOTAL		**2,425,633**	**3,216,514**		

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