

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



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

Prepared by

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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 Sustainability, Environment, Water, Population and Communities

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Cover photo of the banded-hare wallabies by Amy Mutton, Peron Captive Breeding Centre.

FOREWORD

Recovery Plans are developed within the framework laid down in Department of Environment and Conservation (DEC) Policy Statements Nos 44 and 50, and the Australian Government Department for Sustainability, Environment, Water, Population and Communities (DSEWPAC) *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 DSEWPAC, 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 May 2012.

CONTENTS

ACRONYMS	iii
ACKNOWLEDGEMENTS	iii
1. SUMMARY	4
2. BACKGROUND INFORMATION	6
2.1 Affected interests	8
2.2 Role and interests of Indigenous people	11
2.3 Benefits to other species	11
2.4 Social and economic impacts	13
2.5 International obligations	14
3. SPECIES INFORMATION	15
3.1 Western barred bandicoot <i>Perameles bougainville</i>	15
3.2 Burrowing bettong <i>Bettongia lesueur</i>	17
3.3 Banded hare-wallaby <i>Lagostrophus fasciatus</i>	21
3.4 Habitat critical to survival	23
3.5 Important populations	24
3.6 Threats	24
3.7 Populations under threat	30
4. RECOVERY PROGRAM	31
4.1 Prior and existing conservation measures	31
4.2 Recovery objectives and performance criteria	36
4.3. Recovery actions	37
4.4 Implementation	42
4.5 Management practices	44
4.6 Guide for decision-makers	44
5. REFERENCES	46
APPENDIX 1: translocation and captive breeding	55

ACRONYMS

ARR	Arid Recovery Reserve
AWC	Australian Wildlife Conservancy
DEC	Department of Environment and Conservation, WA (formerly CALM)
DENR	Department for Environment and Natural Resources, South Australia
RTDBF	Return to Dryandra Breeding Facility
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities
EPBC Act	Commonwealth <i>Environment Protection and Biodiversity Conservation Act 1999</i>
NP	National Park
NSW	New South Wales
PCBC	Peron Captive Breeding Centre
PVA	Population Viability Analysis
SA	South Australia
SBSJV	Shark Bay Salt Joint Venture
ULCBPG	Useless Loop Community Biosphere Project Group
WA	Western Australia
WAWC Act	Western Australia <i>Wildlife Conservation Act 1950</i>
WS	Wildlife Sanctuary

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1. SUMMARY AND STATUS

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:	EPBC – Endangered, WAWC Act- threatened
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:	Potoroidae
Common name:	Boodie
DEC Region:	Midwest, Pilbara
DEC District:	Shark Bay, Pilbara
Shire:	Shark Bay, Ashburton
Current status of taxa:	<i>B. l. lesueur</i> : EPBC – Vulnerable WAWC Act - Threatened <i>B. l.</i> unnamed subspecies: EPBC – Vulnerable WAWC Act - Threatened
Habitat requirements:	Open habitat with some ground cover and soil suitable for the construction of warrens beneath calcrete or granite caprock.

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:	EPBC – Vulnerable WAWC Act - Threatened
Habitat requirements:	Areas of dense heath and shrub thickets
Recovery Team:	Shark Bay Marsupials Recovery Team

Long term objective:

The long term objective of the recovery program is to undertake conservation actions which:

Ensure the survival and maintain or improve the status of the western barred bandicoot and Shark Bay Islands subspecies of the burrowing bettong and banded hare-wallaby and Barrow Island subspecies of the burrowing bettong based on the IUCN criteria 2001 extent of occurrence¹.

¹ Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon, excluding cases of vagrancy. This measure may exclude discontinuities or disjunctions within the overall distributions of taxa (e.g. large

Recovery actions

1. Protect the wild populations and their habitat
2. Monitor the wild populations
3. Maintain captive populations (where appropriate)
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. Conduct research to determine the genetic relationships of isolated populations of each species
7. Enhance community participation and education in the recovery of the western barred bandicoot, the burrowing bettong and banded hare-wallaby
8. Manage the recovery program

areas of obviously unsuitable habitat). Extent of occurrence can often be measured by a minimum convex polygon (the smallest polygon in which no internal angle exceeds 180 degrees and which contains all the sites of occurrence).

2. BACKGROUND INFORMATION

This recovery plan covers four marsupial taxa listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Table 1). Each of the taxa is listed under Schedule 1 'Fauna that is likely to become extinct or is rare' under provisions of Section 14 of the Western Australian *Wildlife Conservation Act 1950*. The plan describes the status, relevant ecology, threats, and the recovery objectives and actions necessary to ensure the long-term survival of these taxa. It is the first national recovery plan for these species.

Table 1. Threatened Shark Bay marsupial taxa

Common name / Indigenous name	Taxonomic name	Status
Western barred bandicoot/ Marl	<i>Perameles bougainville bougainville</i>	E*
Burrowing bettong/ Boodie (Shark Bay island subspecies)	<i>Bettongia lesueur lesueur</i>	V
Burrowing bettong / Boodie (Barrow Island subspecies)	<i>Bettongia lesueur</i> unnamed subspecies	V
Banded hare-wallaby- Merrnine or Munning	<i>Lagostrophus fasciatus fasciatus</i>	V^

V– Vulnerable, E – Endangered

* as western barred bandicoot (Shark Bay subspecies)

^ as banded hare-wallaby (Shark Bay subspecies)

The four listed threatened taxa represent the only extant taxa of their respective species: western barred bandicoot (*Perameles bougainville*), burrowing bettong (*Bettongia lesueur*) and banded hare-wallaby (*Lagostrophus fasciatus*). The recovery plan therefore covers all remaining examples of these three species. The species have each contracted markedly in range and wild populations are now found only on islands off the coast of Western Australia. They are referred to within this plan as 'threatened Shark Bay marsupials' as most of the remaining populations are within the Shark Bay region of WA (Figure 1).

The islands which contain populations of threatened Shark Bay marsupials are: Bernier Island (approximately 44 km²), Dorre Island (53 km²) (Figure 1), Barrow (233km²), and Boodie Islands (Figure 2). All are Class A Nature Reserves, managed by DEC. Remaining sites with existing recovery work are mostly National Parks or Private conservation reserves. Recovery of the western barred bandicoot and burrowing bettong occurs within the remaining pastoral leases of Carrarang Station and Lorna Glen with support from DEC. Private conservation sites and those on pastoral leases are very important to the recovery of these species, as is the involvement of both Government and non-Government interests. The common feature of all sites is the absence or control of introduced predators through annual baiting and targeted eradication programs mostly implemented by DEC.

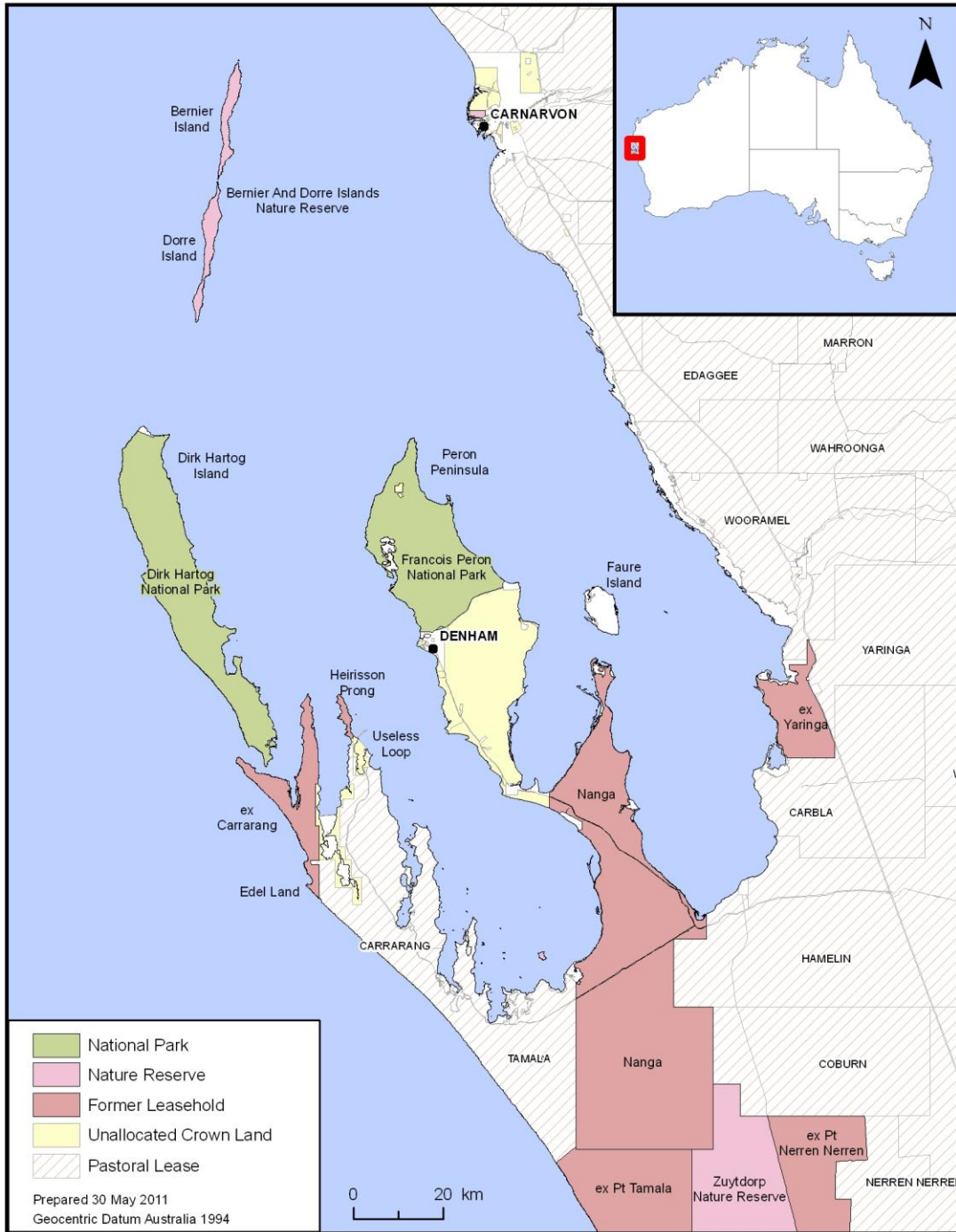


Figure 1: Shark Bay WA, showing Bernier, Dorre, Dirk Hartog and Faure Islands, Heirisson Prong and Peron Peninsula.

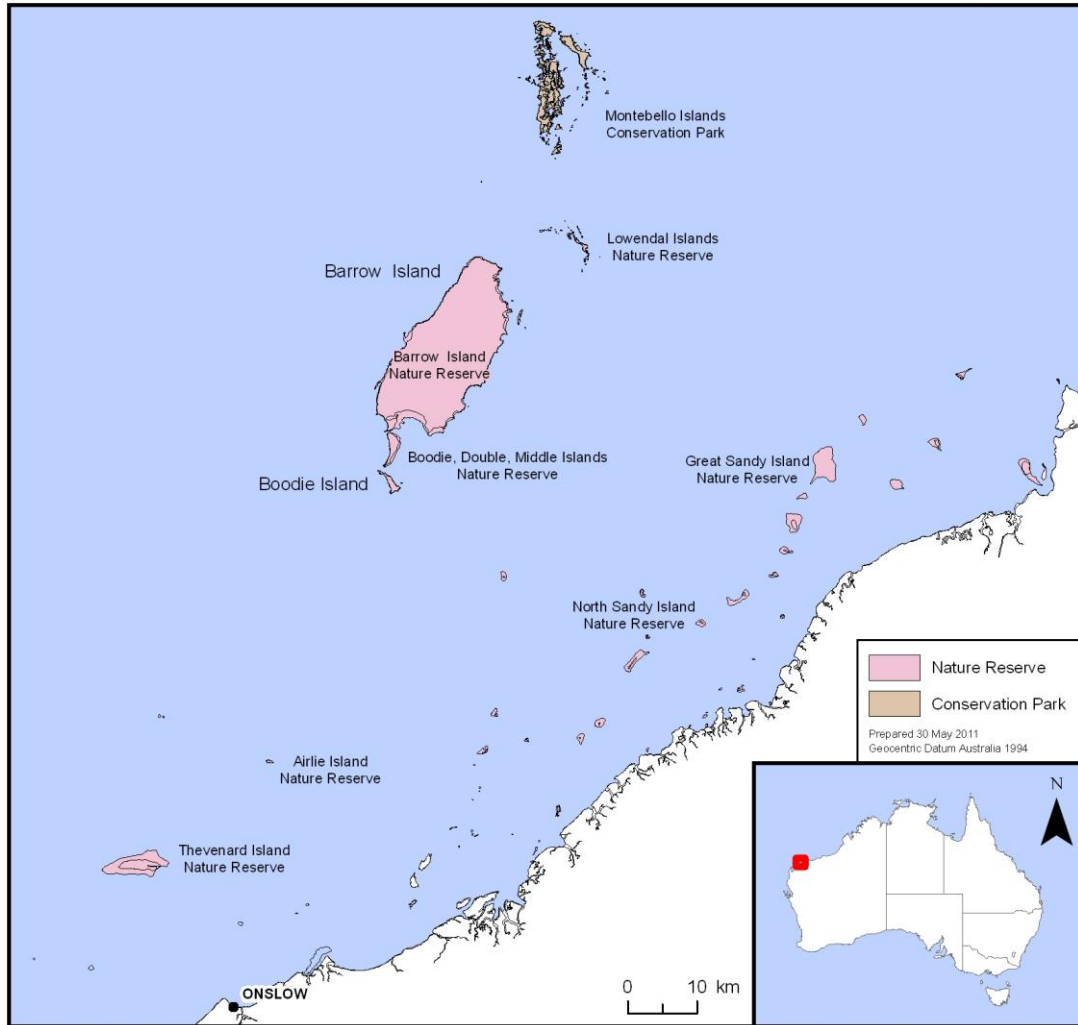


Figure 2: Location of Barrow and Boodie Islands, WA.

2.1 Affected interests

Interests affected by and involved in the implementation of this recovery plan include:

Department of Environment and Conservation (Western Australia)

DEC manages:

- Bernier, Dorre, Barrow and Boodie Islands, and the François Peron National Park, including their resident wild, captive and reintroduced populations of threatened mammals and Dirk Hartog Island National Park.
- *Project Eden*, aims to reconstruct and rejuvenate an entire ecosystem on the 105 000 ha Peron Peninsula, by controlling introduced predators and reintroducing a suite of native fauna (Morris *et al.* 2004; Hardman and Moro 2006). *Project Eden* was launched in 1994. Fox baiting was implemented in 1995 and feral cat control in 1996. Reintroductions have included malleefowl, greater bilbies, woylies, quenda and chuditch.
- Peron Captive Breeding Centre is the captive breeding facility for Project Eden in Shark Bay, Western Australia. This facility provides quality source stock for reintroductions and has successfully bred the following species banded hare-wallaby (BHW) (*Lagostrophus fasciatus*), western barred bandicoot (WBB) (*Perameles bougainville*), the mala (*Lagorchestes hirsutus*), greater bilby (*Macrotis lagotis*) and malleefowl (*Leipoa ocellata*). There are multiple enclosures at the facility with the larger of these built to accommodate

wallabies (30 enclosures that measure 8 x 12m and a further 6 that measure 24 x 12m) and include custom built ground shelters. Additional enclosures are available for the rearing of other smaller species.

- The 24,000 ha Dryandra Woodland south-east of Perth, its surrounding area and the Return to Dryandra Field Breeding Facility (RTDBF). The RTDBF was established in 1997, which involved the construction of two ten-hectare captive breeding enclosures of natural vegetation.
- The *Western Shield* fox control program instigated in 1996 over an area of 3.5 million ha of land (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).
- the Shark Bay World Heritage property.
- the Recovery Team.

South Australian Department for Environment and Natural Resources (DENR)

DENR manages the *Arid Recovery Project* in partnership with BHP Billiton and the University of Adelaide. This project commenced in 1997. Initially 1,400ha area was fenced and rabbits, cats and foxes removed (Arid Recovery Project 2002). The Arid Recovery Reserve (ARR) is now 12 300 ha and has reintroduced populations of burrowing bettong, western barred bandicoot, greater stick-nest rat, greater bilby, numbat and woma python. Introduced predators and rabbits have been eradicated from 6,000 ha of the ARR, and control is ongoing in the remaining 2,600 ha 'Red Lake expansion area' (Arid Recovery 2011). The project aims to facilitate ecological restoration of an arid ecosystem through partnerships between mining, pastoral, tourism and conservation organisations. Other aims include researching this restoration and providing opportunities for education and training (Arid Recovery Project 2002).

Australian Wildlife Conservancy (AWC)

AWC is responsible for the management of a number of properties throughout Australia, including:

- Faure Island in WA - a 5,800 ha pastoral lease within the Shark Bay World Heritage Area, with resident introduced populations of western barred bandicoots, burrowing bettongs, banded hare-wallabies and Shark Bay mouse (*Pseudomys fieldi*). The island is managed for conservation, and is free of introduced predators and rabbits. All feral goats have been culled (Richards 2007). Feral cats were eradicated from the island in 2001 by DEC (Algar *et al.* 2001; Algar and Burrows 2004).
- Yookamurra Wildlife Sanctuary in South Australia – a 5,000 ha property, with a population of captive burrowing bettongs in a four ha predator-proof enclosure was upgraded in 2006 (formerly within a 1,100 ha enclosure). Burrowing bettongs and bilbies were released into the sanctuary in 2006, once feral animals were eradicated.
- Scotia Wildlife Sanctuary in New South Wales – a 65,000 ha property, with a population of burrowing bettongs and bilbies in a second, larger 4,000 hectare fenced area (stage 2) is now complete.

The intention at these properties is to establish free-ranging and self-sustaining populations of these species within large enclosures.

Useless Loop Community Biosphere Project Group Inc. (ULCBPG)

The Useless Loop Community Biosphere Project Group Inc. (ULCBPG) is responsible for the management of the Heirisson Prong Community Biosphere Reserve and its resident reintroduced populations of the burrowing bettong (Short and Turner 2000; Richards and Short 2003; Richards *et al.* 2004). Heirisson Prong is a 1,200 ha peninsula fenced at its base to exclude introduced predators (Short *et al.* 1994). It was established in 1989 with the support of the local ULCBPG, mining company Shark Bay Salt Joint Venture (SBSJV) and the CSIRO. It is dedicated to nature conservation, education and recreation (Short 1999b).

BHP Billiton

WMC Resources supported the Arid Recovery Project near Roxby Downs in SA from 1997 to 2005, by providing infrastructure and financial assistance to assist in the re-establishment of western barred bandicoot and burrowing bettongs. BHP Billiton acquired WMC Resources in 2005 and is continuing to support the Arid Recovery Project. However, a project to expand the Olympic Dam mine at Roxby Downs (received Federal government approval on 10 October 2011- reference EPBC 2005/2270) has the potential to affect the Arid Recovery Project (P. Copley² pers. comm.), 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). Further information regarding the project's approval and conditions can be found at <http://www.environment.gov.au/epbc/index.html>.

Pastoral lessees - Carrarang Station

Part of the Carrarang Station lease has been surrendered to DEC. Management activities by DEC include feral animal control, mainly removal of goats through shooting, fence maintenance and baiting. Nanga Station has also been purchased by DEC and baiting for foxes was prioritised again for 2011, particularly in the northern half and buffer to Hamelin Pool Nature Reserve. Tamala Station is also partly owned by DEC.

Recovery of the burrowing bettong occurs within the existing pastoral leases of Carrarang Station in WA. Most recovery actions on these lands are implemented with DEC support and involve baiting and control programs of foxes and cats and to a lesser degree fence maintenance.

Shark Bay Salt Joint Venture (SBSJV)

SBSJV harvest salt within the vicinity of recovery actions for burrowing bettongs at Useless Loop in Shark Bay. The mining company supports a number of recovery actions related to the reintroduction of this threatened mammal adjacent to their existing mining lease, and within their current pastoral lease, by providing infrastructure and financial assistance. This includes support to ULCBPG to manage Heirisson Prong and funds for feral animal control such as baiting and fence maintenance.

Local communities

This includes residents, landholders and all community members.

Indigenous communities

This includes the Anangu indigenous community, members of the Mutijulu Community, and the Yadgalah Aboriginal Corporation.

The Shark Bay Shire Council

The Council maintains a community-based interest and support for the recovery of these species (B. Cane³ pers. comm.).

Chevron

Staff 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 during their induction.

University of Adelaide, South Australia

The University is a partner in the Arid Recovery project

² Peter Copley, Senior Ecologist, Department for Environment and Heritage, SA.

³ Bryan Cane, Shark Bay Shire Councilor and Vice President of the ULCBPG Inc.

Wildlife Research and Management

Wildlife Research and Management monitor the burrowing bettong population at Heirisson Prong, and offer advice to the ULCBPG.

2.2 Role and interests of Indigenous people

Recovery actions under this plan include consideration of the role and interests of Indigenous communities in the region that the plan pertains to, and this is discussed in the recovery actions. Input and involvement was sought from Anangu indigenous groups that have an active interest in areas through the Uluru–Kata Tjuta Board of Management through a series of meetings where comments were sought in relation to the management of the park and fauna such as the western barred bandicoot, burrowing bettong or banded hare-wallaby. In preparation of the Uluru-Kata Tjuta National Park Management Plan 2010-2020 the knowledge of elder Anangu about locations of fauna species that have disappeared was recorded. This information was incorporated into the workshop proceedings to identify priority species and set out key principles for the reintroduction of fauna (Gillen *et al.* 2000).

The Aboriginal Sites Register maintained by the Department of Indigenous Affairs lists significant sites on Bernier and Dorre Islands in Shark Bay, due to the presence of human skeletal material, burial sites and artefacts/scatter, and on Barrow Island 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, 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 if sites are discovered then traditional owners will be consulted and actions taken to minimise disturbance.

Indigenous people residing in the communities of Denham and Useless Loop in Shark Bay, include members of the Yadgalah Aboriginal Corporation based in Denham. The Yadgalah Aboriginal Corporation expressed interest in 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.

Two indigenous people from outside the Shark Bay region were 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. Indigenous personnel are employed by DEC through the Mentored Aboriginal Training and Employment Scheme (MATES) at Shark Bay, and work programs include involvement in *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.

2.3 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; Burbidge and McKenzie 1989). Predator control may also 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 ocellata*, woylies *Bettongia penicillata ogilbyi*, quenda *Isoodon obesulus fusciventer*, greater bilbies *Macrotis lagotis and chuditch (Dasyurus geoffroii)* at Peron Peninsula (Morris *et al.* 2004),

greater bilbies to Dryandra Woodland (N. Marlow⁴ pers. comm.), 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, greater stick-nest rats, burrowing bettongs and banded hare-wallabies at Faure Island (AWC 2002). Numerous threatened mammals have been reintroduced by DEC at other Western Shield sites throughout WA, 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 threatened species that occur in the region (e.g. thick-billed grasswren *Amytornis textilis textilis*, woma python *Aspidites ramsayi*; C. Sims⁵, pers. comm.).

The ARR 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; Moseby *et al.* 2009).

There are a number of possible negative impacts of recovery actions 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 was conducted and showed non-target bait uptake to be minimal (Algar and Burrows 2004). The registration of the novel sausage cat bait Eradicat® is now under consideration by the Australian Pesticides and Veterinary Medicines Authority (APVMA) (D. Algar⁶, pers. comm.)

Broad-scale baiting for foxes and dingoes 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.

Implementation of the disease risk management strategy (Chapman *et al.* 2008) will benefit a broad spectrum of native species.

⁴ Dr Nicky Marlow, Senior Research Scientist, DEC Perth.

⁵ Dr Colleen Sims, Project Eden Coordinator, Shark Bay District, DEC Denham

⁶ Dr David Algar, Senior Research Scientist, Department of Environment and Conservation

2.4 Social and economic impacts

Mining

The majority of recovery actions are unlikely to impact negatively on mining interests in the region. The recovery actions are 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. Increases in rabbit numbers may 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 used in the salt-production process (via rabbits drowning). Rabbit control measures such as 1080 baiting, myxoma virus and the rabbit calicivirus disease may assist in reducing the impact of rabbits within the mine site.

Pastoral

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 Carrarang Station and Faure Island as conservation goals have typically replaced pastoralism. Faure Island is currently leased and managed by AWC for the purpose of conservation.

Broad scale fox control may offer benefits in terms of pastoral production, by reducing the loss of livestock. Carrarang, Tamala, Nanga and Coburn Pastoral Leases in the Shark Bay region have existing 1080 baiting programs to control foxes to protect livestock.

Tourism

Tourism is now regarded as the major industry in Shark Bay (Reark Research *et al.* 1995) and is focussed strongly on the region's unique natural environment. Recovery actions 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 National Park.

Dorre Island is currently inaccessible to tourists. Bernier Island is accessible for day visits by boating traffic in the area (usually local) but overnight camping does occur. 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. Faure Island is currently inaccessible to tourists but AWC plan to implement a managed visitor program in the future (AWC 2002).

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 and 44,138 in 2009/10 financial year) (DEC VISTAT Database, visitor statistics, 2011). DEC has run a number of Landscape Expeditions to Peron Peninsula to assist with *Project Eden*, the most recent in 2006. 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. 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 had 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.

Local Community

It is likely that many of the recovery actions for threatened Shark Bay marsupials will increase local community knowledge, pride and involvement in the conservation of the threatened mammals and their habitat. In particular, opportunities for employment would be well received. Recovery actions are unlikely to impact negatively on the local communities within the Shark Bay region, in particular the township of Denham, and the mining community of Useless Loop, in the Narrogin region of WA, and at Roxby Downs in SA.

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 engaged and know 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 engagement 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.

2.5 International obligations

The western barred bandicoot, burrowing bettong and banded hare-wallaby are listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix I (2010), as species threatened with extinction for which international trade in specimens of these species is permitted only in exceptional circumstances.

The taxa 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.

Under the EPBC Act any person proposing to undertake actions which may have a significant impact on the world heritage values of a declared World Heritage property should refer the action to the Federal Minister for Environment. The Minister will determine whether the action requires EPBC Act assessment and approval. The world heritage values of a property are "the natural heritage and cultural heritage contained in the property". The lead agency for managing the Shark Bay World Heritage property is DEC.

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

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

This recovery plan is consistent with the obligations under these international agreements, and will help Australia meet these obligations.

3. SPECIES INFORMATION

3.1 Western barred bandicoot *Perameles bougainville*

Taxonomy and description

The western barred bandicoot was first described from a specimen taken at Peron Peninsula in Shark Bay (Figure 1) by naturalists Quoy and Gaimard in 1817. Two subspecies are currently 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 the species, and limited morphological data suggest 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). They are lightly built animals with large erect ears. Their feet are elongated, with the second and third toes of the hind feet 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).

Distribution and abundance

Western barred bandicoots were widely distributed across the southern mainland of Australia at the time of European settlement but have been extinct on mainland Australia since the 1930s (Brooker 1977; Copley *et al.* 1989; Richards and Short 2003). They occurred in a broad arc from Onslow on the north-west coast of WA, through the WA Wheatbelt, Nullarbor Plain, and arid and semi-arid SA, Victoria and NSW to the Liverpool Plains. The extant subspecies has remained only on Dorre and Bernier Islands in Shark Bay, WA (Figure 3).

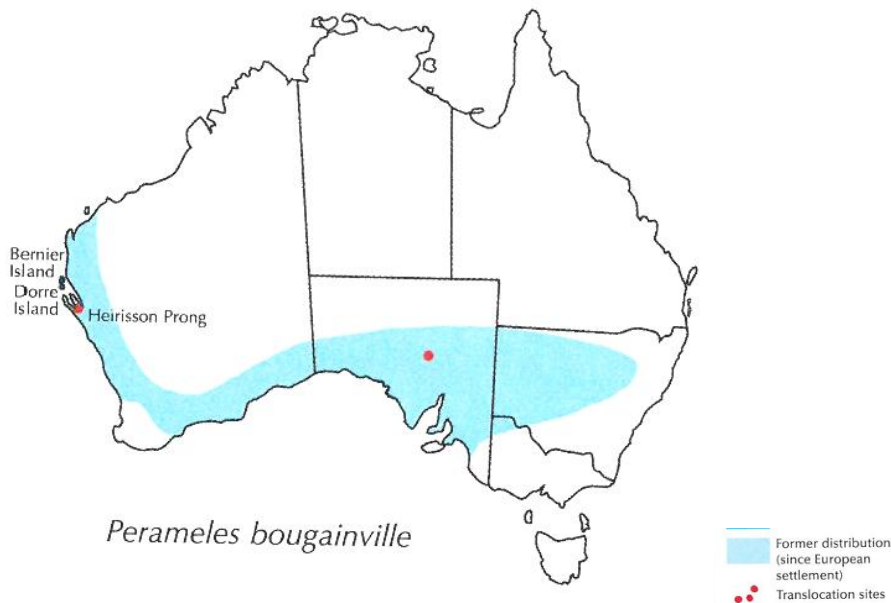


Figure 3: Distribution of wild populations of the western barred bandicoot (from van Dyck and Strahan (2008), and including historical and subfossil records)

The remnant wild populations on Dorre and Bernier Islands, estimated to be 757 and 959 respectively as of 2010, are small and subject to substantial fluctuations due to weather (Short

and Turner 1993; Short *et al.* 1997a). In addition, the species was reintroduced to Heirisson Prong at Shark Bay in 1995 and to Faure Island in Shark Bay in October 2005 (Table 2) (Richards and Short 1997; Richards and Short 2003), and 16 individuals from Bernier Island to the Arid Recovery Reserve (ARR) at Roxby Downs in SA (Arid Recovery Project 2002; Arid Recovery 2004). Western barred bandicoots now occur throughout the ARR Main Enclosure and more recently in the Northern Expansion and First Expansion. At Heirisson Prong they are presumed locally extinct since 2008. Details of re-introduction attempts and captive populations are in Appendix 1.

Table 2: Western barred bandicoot populations and groups

Population/group		Size
Wild populations:	Bernier Island (959)	Total of both islands approx. 1716 (2010)
	Dorre Island (757)	
Translocated groups:	ARR (SA)	70-100 (2011)
	Faure Island	100 (2009)

Translocations in **bold** are considered successful as they are self-sustaining populations

Habitat

The western barred bandicoot was an inhabitant of a wide variety of vegetation types in the southern arid and semi-arid zones. Gould (1863) described the range in WA 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 western central Australia (Jones 1923-25). On the western slopes of NSW they were recorded from the stony ridges, which branch off from the ranges towards the Darling and Namoi Rivers. In SA 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 Shark Bay islands populations are widely distributed through the islands in all habitats, but most likely found in tall scrub (Short *et al.* 1998). At night they are commonly found in the sandhills and seen occasionally during the day amongst low, dense scrub (Ride and Tyndale-Biscoe 1962). Friend and Burbidge (1995) reported they were common in the scrub associated with stabilised dunes behind the beaches and also occurred on the open steppe associations. At the ARR they survive in very open country, suggesting 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 but will forage at night in the more open chenopod swales (K. Moseby⁷, pers. comm.; Arid Recovery 2004).

Biology and Ecology

Western barred bandicoots are 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. They 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).

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 vacating of the pouch. Females reach sexual maturity at about 175 g, and males a little later at about 195 g (Short *et al.* 1998).

⁷ Katherine Moseby, Arid Recovery Project, Roxby Downs, South Australia

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 bred continuously if environmental conditions were good and individuals survived and bred for up to four years (Richards and Short 2003). Western barred bandicoots in the Return to Dryandra enclosure were capable of breeding throughout the year; however, the majority of females bred 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 bred twice a year with only a very few producing three litters per year (N. Thomas unpublished data).

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).

Most movements by western barred bandicoots on Bernier and Dorre Islands are less than 400 m; however, males have been recorded moving up to 1020 m over one day, and females up to 490 m over a two-day period (Short *et al.* 1998). Home range sizes for male and female western barred bandicoots on Dorre Island are 2.5 and 1.4 ha (at high density), and 14.2 and 6.2 ha (at low density), respectively (Friend and Burbidge 1995). The home range of both males and females overlap (Short *et al.* 1998). The movements of reintroduced western barred bandicoots at Heirisson Prong after release did not pose significant problems for re-establishment (Richards and Short 2003).

At Heirisson Prong 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). In this case, movement away from the trap lines may have resulted in an underestimate of survival and longevity. At RTDBF western barred bandicoots 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. Butcher⁸ pers. comm.).

Although there are no published results for the western barred bandicoot, they are thought to possess a high tolerance to sodium monofluoroacetate ('1080' poison) (King 1988). 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 assumed 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.

3.2 Burrowing bettong *Bettongia lesueur*

Taxonomy and description

The burrowing bettong was first described by naturalists Quoy and Gaimard in 1824, from a specimen collected on Dirk Hartog Island in 1817. Several forms have been identified, including *Bettongia lesueur lesueur* from Bernier and Dorre Islands, and an undescribed subspecies from Barrow Island. The extinct mainland subspecies have been referred to by a

⁸ June Butcher, Manager, Kanyana Native Fauna Rehabilitation Centre

number of names however, *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).

The burrowing bettong is a rat-kangaroo and a member of the Family Potoroidae. 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. Donaldson⁹ pers. comm.). 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.

Dorre Island animals are typically larger than those on Bernier Island, while 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). Preliminary findings of genetic research suggest the 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 (2002), which is based upon the Evolutionary Species Concept (Wiley 1978; Wiens and Penkrot 2002; F. Donaldson⁹, pers. comm.).

Distribution and abundance

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 WA to the western slopes of NSW near Bourke (Short 1998; Short 1999a), through to south-western Queensland (Van Dyck 2005). The last records on mainland Australia were in the 1920s in NSW (Frith 1973) and in the SA 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 it may have persisted in the central Australia deserts until the 1960s, and Finlayson wrote in 1961 that burrowing bettongs had “now been almost eliminated” from north-western SA. The last records of specimens on the mainland in WA were from East Pingelly in the south-west (Norris and Pickering 1995).

Wild populations survive on Bernier and Dorre Islands in Shark Bay, and on Barrow and Boodie Islands in WA (Short and Turner 1993) (Figure 3, Table 3). The Boodie Island population was unintentionally exterminated in 1985 during a program to rid the island of black rats (*Rattus rattus*), and animals were subsequently reintroduced from Barrow Island in 1993 (Morris 2002).

⁹ Felicity Donaldson, PhD student, Department of Animal Biology, UWA

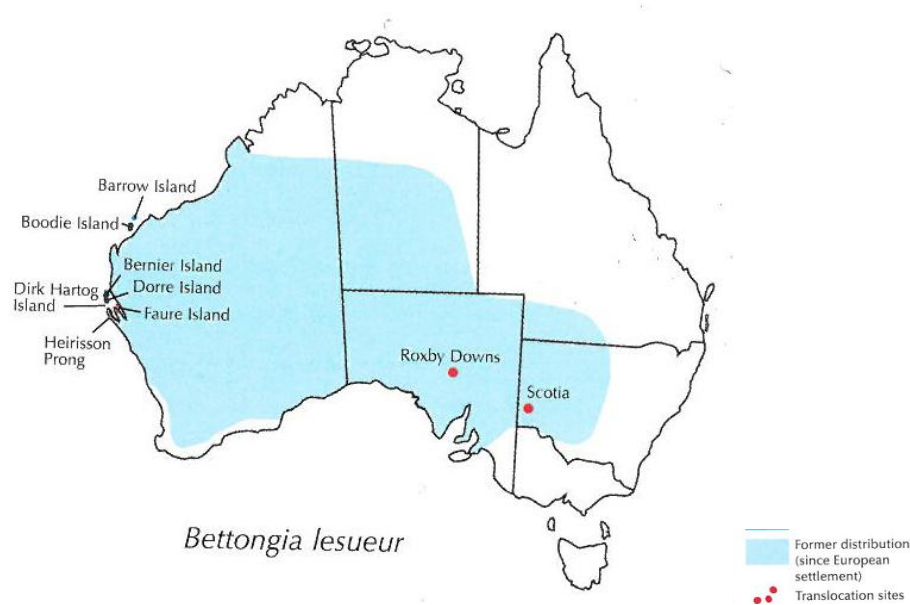


Figure 3: Distribution of wild populations of the burrowing bettong (adapted from van Dyck and Strahan (2008), and including historical and subfossil records). Arrows indicate Bernier, Dorre, Barrow and Boodie Islands.

There are estimated to be approximately 4,000 burrowing bettongs on Bernier and Dorre Islands based on estimates between 2006-2010. The remnant wild burrowing bettong populations are small (600 - 2500 per island) and subject to substantial fluctuations due to weather (Short *et al.* 1997a). The populations on Barrow and Boodie Islands are estimated to be 3,000 and 200 respectively (K. Morris¹⁰ pers comm.). The Boodie Island population is regarded as self sustaining.

The species was reintroduced from Dorre Island to Heirisson Prong in 1992. Further reintroductions occurred to the ARR in 1999 (Arid Recovery Project 2002; Arid Recovery 2004, Arid Recovery 2010), Faure Island in 2002, Scotia WS in 2004 (Table 3). All these groups are likely to be free living as long as the sites can be maintained free of exotic predators. 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. There has been some progress in destocking some of these areas but parts of the lease remain active. A number of other attempted translocations have been unsuccessful (see Appendix 1 for details). A captive population are currently held at the Yookamurra wildlife sanctuary (Table 3). Details of re-introduction attempts and captive populations are in Appendix 1.

¹⁰ Dr Keith Morris, Senior Principal Research Scientist, Department of Environment and Conservation, WA.

Table 3: Burrowing bettong populations and groups

Population/Group	Location	Size (year)
Wild populations:	Bernier Island	842 (2010)
	Dorre Island	3291 (2010)
	Barrow Island	3 000 (2011)
Translocated groups:	Boodie Island	200 (2011)
	Heirisson Prong	355 (2010)
	ARR	2260 (2010)
	Faure Island	800+ (2010)
	Scotia WS	140 (2006)
	Yookamurra WS	65 (2007)
	Lorna Glen	100 (2011)

Translocations in **bold** are considered successful as they are self-sustaining populations

Habitat

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 ARR they prefer to dig their warrens on the dune slopes or beneath limestone calcrete outcrops, but forage throughout all habitats (Arid Recovery Project 2002; K. Moseby⁶, pers. comm.).

Biology and Ecology

Burrowing bettongs 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. Burrowing bettongs consume a wide variety of foods, including tubers, bulbs, seeds, stems, nuts (*Santalum acuminatum*), grasses, and invertebrates, and have been seen scavenging carcasses (Shorridge 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). At Heirisson Prong the diet comprises predominantly hypogean fungi, fruit, seed, forbs, and arthropods in winter, and browse from shrubs such as *Acacia ligulata*, *Senna glutinosa* subsp. *chatelainiana*, *Eremophila* spp., *Pimelea microcephala*, and *Olearia* spp., fruit, seed, stem, and some forbs in summer (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. Sims⁴, pers. comm.)

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. Donaldson⁸ (pers. comm.) has observed four nipples in most females on Barrow Island. Two incidences of twinning have been recorded at Heirisson Prong, one at Faure Island, and a fourth on Barrow Island (F. Donaldson⁸ pers. comm.). 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 vacating of the pouch (Freeguard *et al.* 2008; 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). 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).

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 and there appears to be a peak in summer coinciding with cyclonic rain (F. Donaldson⁸ pers. comm.). Reintroduced animals at Heirisson Prong may breed continuously, though there was a peak between February and September and some evidence of a decline in breeding in late spring and early summer (Short and Turner 2000). Within the RTDBF enclosure, burrowing bettongs bred all year round, with a slight reduction over January/February and a peak in August (N. Thomas unpublished data). Females mostly produced two to three young per year and a few produced four (N. Thomas unpublished data).

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. Donaldson⁸ pers. comm.). The average home range sizes for males and females at Heirisson Prong are 107 and 86 ha respectively (Robley 1999), and on Barrow Island are 133 and 98 ha (Short and Turner 1989) for males and females respectively. The average home range size for reintroduced animals on Faure Island is 101 ha (F. Donaldson⁸ pers. comm.). 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 (Parsons *et al.* 2002b). The young animals dispersed at between 170 and 250 days of age, coinciding with the period associated with weaning to sexual maturity.

Longevity for burrowing bettongs in the wild on Bernier and Dorre Islands is over three years for some animals (Short and Turner 1999), and at Heirisson Prong has been up to 11 years (J. Short *et al.* unpublished data).

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

3.3 Banded hare-wallaby *Lagostrophus fasciatus*

Taxonomy and description

William Dampier first reported the banded hare-wallaby in 1699. Three subspecies have been described: *Lagostrophus fasciatus fasciatus* from Bernier, Dorre and possibly Dirk Hartog Islands, *L. fasciatus albipilis* from the south-west of WA and *L. fasciatus baudinettei* from SA, NSW and Victoria (Thomas 1886; Maxwell *et al.* 1996; Helgen and Flannery 2003). It was known as “merrnine” or “munning” in the south-west of WA (Shortridge 1909). Both the Dirk Hartog Island and the mainland populations are presumed extinct. The last specimen was collected in 1927 in SA (Helgen and Flannery 2003).

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. Adults weigh an average of 1600 g and there is no sexual dimorphism (Richards *et al.* 2001). Animals on Dorre Island have a shorter pes length than those on Bernier Island but no other morphological, chromosomal or blood allozyme differences have been found (Courtenay 1993; Richards *et al.* 2001). This provides support for the existing taxonomy, which does not distinguish between the two island populations.

Distribution and abundance

Banded hare-wallabies formerly occurred in an arc through south-west WA (Prince 1995; Figure 5). They were last recorded on mainland Australia in 1906 in WA (Shortridge 1909; Short and Turner 1992) and in 1927 in SA (Helgen and Flannery 2003). Recent fossil remains extended across the Nullarbor Plain (Lundelius 1957; Baynes 1987), through parts of southern SA (Helgen and Flannery 2003) and into south-eastern Australia in Victoria and NSW (Wakefield 1964; Marshall 1974). They have survived as wild populations only on Dorre and Bernier Islands in Shark Bay.

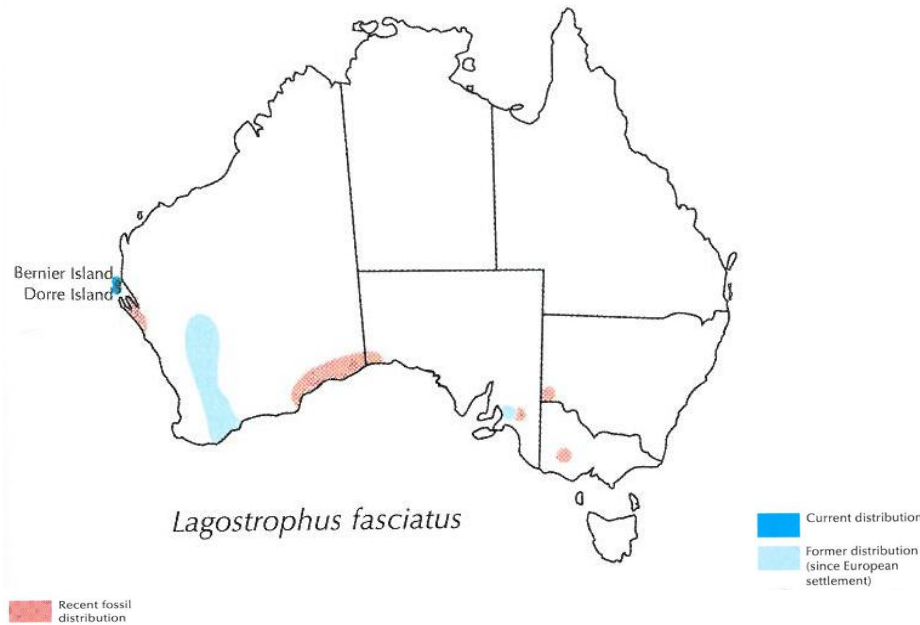


Figure 4: Distribution of the banded hare-wallaby (from van Dyck and Strahn (2008), and including historical and subfossil records).

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 combined banded hare-wallaby 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) and more recently as 2655 (2009) (DEC unpublished data) suggesting a marked decline in the wild populations. Banded hare-wallabies were first translocated to Faure Island in 2004, with additional animals translocated in 2005-2010. Details of re-introduction attempts and captive populations are in Appendix 1

Table 4: Banded hare-wallaby populations and groups

Population/Group	Location	Size (year)
Wild populations	Bernier Island	Total 2655(2009)
	Dorre Island	see above
Translocated group	Faure Island	52+ (2010)
Captive group	PCBC	19 (2010)

Habitat

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". The species formerly occupied areas of dense cover in *Eucalyptus* woodlands in south-western Australia (Shortridge 1909). 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 oleifolius*, *Diplolaena dampieri*, and *Ficus platypoda* (Short and Turner 1992) and Hardman and Moro (2006) used dense *Lamachea* shrub habitat during failed.

Biology and Ecology

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 PCBC, banded hare-wallabies have been regularly observed browsing on *Acacia sclerosperma*, *A. tetragonophylla*, *A. ramulosa*, and *A. ligulata* (C. Sims⁴, pers. comm.). They will eat leaves (live and dead), bark, flowers and seed-pods of many of these species.

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 young per year, occasionally two if environmental conditions are particularly favourable (Richards *et al.* 2001). Their gestation period is thought to be about 30 days within the PCBC (C. Sims⁴, pers. comm.), and varies between 20 to 42 days for similar sized macropods (Tyndale-Biscoe and Renfree 1987). In captivity at the PCBC pouch life is about six months, with up to another 1 - 2 months as young at foot and still suckling (C. Sims⁴, pers. comm.). The smallest female carrying pouch young on Bernier and Dorre Islands weighed 1,000 g (Richards *et al.* 2001) and in captivity at the PCBC as small as 550 g (C. Sims⁴, pers. comm.). 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 PCBC 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. Sims⁴ pers. comm.). Hardman (2006) recorded most new pouch young in April and May in the reintroduced animals in François Peron NP. Banded hare-wallabies in the RTDBF 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).

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 PCBC animals have survived for 15 years (C. Sims⁴, pers. comm.). The average home range of a small sample of banded hare-wallabies reintroduced to François Peron NP was 11 ha (Hardman 2006).

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

3.4 Habitat critical to survival

Habitat features critical to the survival of the western barred bandicoot include areas of dense ground cover to avoid predators, with leaf litter for constructing nests, and a minimum of introduced predators.

Habitat features critical to the survival of the burrowing bettong include areas of open habitat with some ground cover and soil suitable for warren construction. 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.

Habitat features critical to the survival of the banded hare-wallaby include areas of dense heath and shrub thickets to avoid 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 WA. However, banded hare-wallabies are unlikely to persist at sites where introduced predators are present (Hardman, 2006).

Habitat critical for all three threatened Shark Bay marsupials includes:

- existing habitat of wild populations: all habitat on Bernier and Dorre (western barred bandicoot, burrowing bettong and banded hare-wallaby), and all habitat on Boodie and Barrow Islands (burrowing bettong)
- potential habitats that present opportunities for reintroduction of one or more of these species: sites that have been managed for the conservation of threatened species for a number of years: Heirisson Prong, Peron Peninsula, Dryandra Woodland, Faure Island, Lorna Glen, Yookamurra and Scotia WS and the ARR

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.

3.5 Important populations

Important populations of western barred bandicoot, burrowing bettong and banded hare-wallaby include:

- All wild populations (on Bernier, Dorre, Barrow and Boodie Islands)
- All reintroduced populations. 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. Reintroduced populations on Heirisson Prong, the Arid Recovery Reserve and Faure Island all appear to be doing well and are therefore significantly important to the continued conservation efforts for burrowing bettongs.
- The reintroduction of burrowing bettongs to Lorna Glen (January 2010-) is in its infancy but may prove important in time.
- Captive populations, to provide animals for reintroduction programs (to supplement the use of animals from the wild populations) and for public education.

3.6 Threats

There 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. These 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 Shark Bay islands 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 predators (foxes and feral cats);
- the introduction of mammalian herbivores (rabbits, sheep, cattle, horses, goats);
- disease;
- a major fire event;
- inappropriate recreation activity, development or management practices, and
- effects from climate change, particularly reduced rainfall and increased wildfires.

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

Introduced predators – the European fox and feral cat

European foxes and cats are absent from Bernier, Dorre, Barrow, Boodie and Faure Islands. They are present across mainland Australia, apart from fenced areas within where foxes have been eradicated (foxes) or controlled (cats at some sites).

Foxes have long been recognised as a threat to native wildlife (e.g. Le Souef and Burrell 1926; Finlayson 1961) and are known to predate on native mammals such as the burrowing bettong (Short *et al.* 2002), and the western barred bandicoot (Finlayson 1961). Cats also consume a wide variety of native mammals, and have been found to consume bandicoots and bettongs when available (Dufty 1991; Christensen and Burrows 1994; Short and Turner 2000).

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 and the wild threatened mammal populations on Bernier, Dorre, Faure, Barrow and Boodie Islands are extremely vulnerable to the introduction of feral cats.

Although Flannery (2003) has suggested that cats may not have been responsible for the extinction of any species in the Australian environment, 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). Reintroductions to the Gibson Desert in 1992 and to Yookamurra Wildlife Sanctuary in SA in 1995, 1996, 2001 and 2004 were thought to have failed because of predation by feral cats (Christensen and Burrows 1994), predation by cats and foxes (J. Bentley¹¹ pers. comm.) and possibly poor habitat quality (Short and Turner 2000). Cats were the primary cause of the failed brushtailed bettong (or woylie; *Bettongia penicillata ogilbyi*) translocation to Nature Reserve (in Western NSW) (Priddel and Wheeler 2004). Predation by cats and foxes is considered the main reason for the decline to extinction on mainland and/or as a threat to western barred bandicoot, by Maxwell *et al.* (1996), Richards and Short (2003), and Richards (2004) and for burrowing bettong on mainland Australia (Short 1998; Short and Turner 2000).

Introduction of 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

¹¹ Dr Joss Bentley, Regional Ecologist, AWC, Scotia Wildlife Sanctuary, NSW

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 coexisted with rabbits in the same warren for some time in SA (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 original 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. 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).

Introduced plants

A small infestation of buffel grass (*Cenchrus ciliaris*) is on Bernier Island. This is not considered a threat because of the small extent and limited ability for the current infestation to spread as it is currently being managed through herbicide application. Biosecurity measures are in place to prevent further introductions of other weeds.

Disease

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 western barred bandicoot population on Bernier Island, and captive populations at Peron Peninsula, Kanyana, RTDBF, Monarto Zoo and the ARR (though no signs have been evident in the released population) were discovered. One of the conditions is a papilloma-like syndrome, which has no effective treatment, and has resulted in the death or euthanasia of over 20 animals from captive colonies at Kanyana and the PCBC. The papilloma-like syndrome was also found in a single individual within the captive population at Dryandra as recently as 2006. However, this disease is thought to have evolved naturally in the population and is species specific (Bennett *et al.* 2008; Woolford *et al.* 2007; Woolford *et al.* 2008). It has been managed at the captive breeding facilities by separating breeding stock. The Heirisson Prong population is presumed “disease-free”. Examinations of >20 animals on Bernier Island by DEC in 2002 and by Murdoch University in 2005 found no evidence of the syndrome. The disease is most often seen in older animals that have already reproduced and therefore it is not considered a major threat.

The second involves ocular disease associated with isolation of *Chlamydia*. 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 results (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 (Woolford *et al.* 2008). In contrast *Chlamydia* is known to be transmissible between people and fauna such as western barred bandicoots that are animal hosts (Kutlin *et al.* 2007). The potential risk of transmission from humans to fauna and vice versa should be considered along with other diseases, under the “disease risk management strategy”, and human visitation to the islands regulated with this in mind.

The extent of the threat of disease is thought to be minimal and manageable; 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.

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 SA (Johnson *et al.* 1988). The disease has caused the death of western barred bandicoots in captivity at Kanyana Wildlife Rehabilitation Centre (J. Butcher¹², pers. comm.). Dickman (1996) suggested that declining populations of native wildlife should be screened to determine whether toxoplasmosis currently has serious deleterious effects. Research has suggested that toxoplasmosis is not prevalent in the native mammal fauna of Shark Bay (P. Adams¹³, pers. comm.).

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. 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 introduced predators, suggests that a fire mosaic is not important on islands (Short and Turner 1992; I. Abbott¹⁴ pers. comm.). Fire issues may be important at sites such as Dryandra Woodland, Lorna Glen and Scotia WS; however, DEC and AWC have implemented fire management regimes in these areas.

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).

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.

¹² June Butcher, Manager, Kanyana Native Fauna Rehabilitation Centre

¹³ Dr Peter Adams, Murdoch University.

¹⁴ Dr Ian Abbott, Research Fellow, DEC, Perth.

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.

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 (see section 4.1 Prior and existing conservation measures). 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 which potentially could get out of control. Recreational activities such as fishing, camping and picnicking are permitted on Heirisson Prong (Short 1999b), where 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 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’, the native animal viewing enclosure that has been constructed at Dryandra Woodland by DEC, where the general public are able to see burrowing bettongs, bilbies, woylies and quenda (*Isoodon obesulus fusciventer*).

Climate change

Climate change will result in a range of effects that will bring further uncertainty to management of these species. Specific threats to these species resulting from climate change effects may be declining annual rainfall and increased frequency of extreme weather events (high temperatures and storms) and associated increase risk of fire. Severe drought is known to affect all species covered in this recovery plan. Recent data from 2006-2010 showed reduced numbers of each of the species on Bernier and Dorre Islands, particularly the western barred bandicoot, following periods of low rainfall (Figure 5).

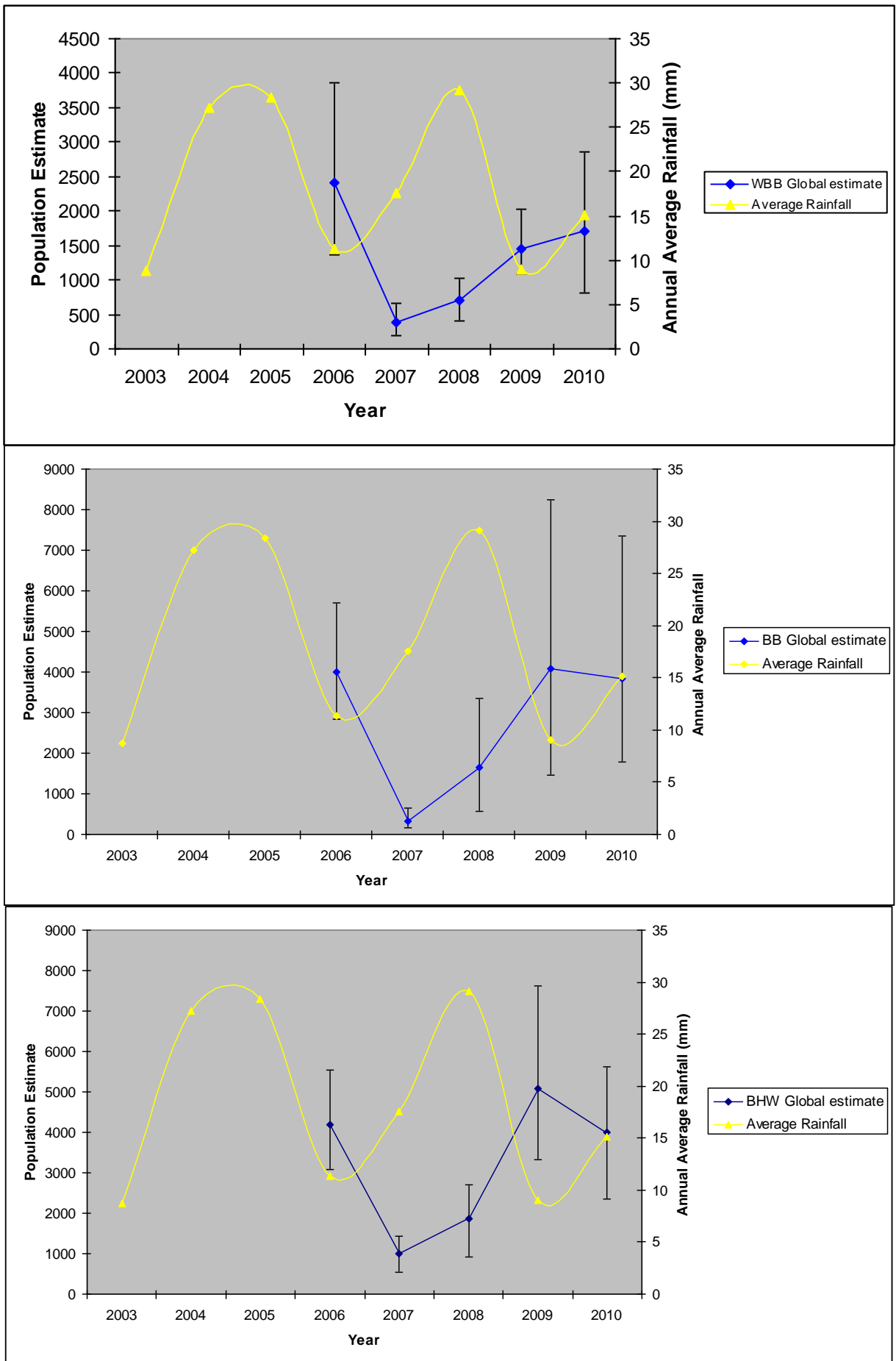


Figure 5: Global population estimates for Bernier and Dorre Island a) western barred bandicoot b) burrowing bettong and c) banded hare wallaby, with average rainfall trends included.

3.7 Populations under threat

Table 6. Locations of taxon populations and vulnerability to possible threats

Taxon	Location of population	Threat
Western Barred Bandicoot	Bernier, Dorre & Faure Islands	Foxes and cats
		Wildfire
		Inappropriate activities recreation & development
	Dorre Island	Transfer of virus from Bernier Island
	ARR (SA)	Foxes and cats
	All locations	Climate change
Burrowing Bettong	Bernier, Dorre & Faure Islands	Foxes and cats
		Wildfire
		Inappropriate activities recreation & development
	Barrow and Boodie Islands	Inappropriate activities e.g. development
	Heirisson Prong	Inappropriate activities recreation & development
		Wildfire
	ARR (SA)	Foxes and cats
	Lorna Glen	
Yookamurra WS		
Scotia WS	Wildfire	
	All locations	Climate change
Banded-hare wallaby	Bernier, Dorre & Faure Islands	Foxes and cats
		Wildfire
		Inappropriate activities recreation & development
	PCBC	Disease/ parasites
	All locations	Climate change

4. RECOVERY PROGRAM

4.1 Prior and existing conservation measures

Existing management documents

The management documents relevant to the Shark Bay region and to the management and translocation of threatened Shark Bay marsupials include:

- Barrow Island Nature Reserve Interim Management Guidelines (CALM 1999a)
- Environmental Impact Statement/Environmental Review and Management Programme for the Proposed Gorgon Development (Chevron Australia 2006)
- Dryandra Woodland Management Plan 1995 – 2005 (Friend *et al.* 1995)
- Faure Island Pastoral Lease Management Plan (Australian Wildlife Conservancy 2002b)
- Heirisson Prong Community Biosphere Reserve Management Plan 1999 – 2004 (Short 1999b)
- Project Eden Draft Strategic Plan 2006
- Shark Bay Terrestrial Reserves Management Plan 2000 – 2009 (Hancock *et al.* 2000)
- The Action Plan for Australian Marsupials and Monotremes (Maxwell *et al.* 1996)
- Western Shield Fauna Recovery Program Draft Interim Strategic Plan 2009-2010 (DEC, 2008)
- Western Shield – Bringing Back our Wildlife (Burbidge *et al.* 1995)

A DEC draft management plan for Barrow Group Nature Reserves and two new departmental final management plans for Shark Bay Terrestrial Reserves and Proposed Reserve Additions and Dryandra Woodland are currently in preparation and will be relevant to this recovery plan once they are formally released.

Management of re-introduction sites

At Heirisson Prong the local community maintains a 2.8 km predator-proof barrier fence, conducts regular 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.

The Uluru-Kata Tjuta National Park 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 enclosure is maintained fox, cat and dingo-free.

At Barrow Island petroleum exploration and production activities began in the mid-1960s, and through cooperative environmental management practices developed initially by West Australian Petroleum Limited 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 including fauna monitoring and surveillance for early detection of biosecurity incursions and a fauna education program for the workforce on the island.

Lorna Glen has been destocked and artificial watering points closed since 2000. In 2003 an annual aerial baiting program was commenced to control foxes and feral cats. Aerial baiting and

strategic trapping at Lorna Glen has maintained feral cat activity at approximately 7-11 cats per 100km, a reduction of approximately 75% over pre control levels. Whilst foxes are rarely detected wild dogs are present and controlled to some extent by the cat baiting program.

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 and the recovery team continue to meet annually. 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.

Management of wild populations

DEC is responsible for the management of Bernier, Dorre, Barrow and Boodie Islands and their resident populations of threatened mammals. The Bernier and Dorre Islands Nature Reserve is not promoted for recreational use, and while day access is allowed, overnight camping is prohibited. The Nature Reserve is designated a 'No Planned Burn Area', and management strategies prohibit all open/wood fires. There is provision for facilitating early detection of fire through local community (predominantly fishermen) and agency communication. In the event of a fire, immediate monitoring will be undertaken to assess whether suppression is warranted or feasible.

Although fires are infrequent within the Shark Bay region, fire management continues to minimise the risk of fire, both on Bernier and Dorre Island, and at reintroduction sites within that region (François Peron NP, Heirisson Prong and Faure Island). Where the potential of fire is more likely, such as Lorna Glen and Scotia Wildlife Sanctuary, there are fire management regimes implemented by DEC and AWC and DEC operates the incident management system for incident response.

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 sometimes 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).

Regular monitoring of the Barrow Island Nature Reserve mammal fauna has been conducted by DEC since 1998, in conjunction with Chevron (and formerly West Australian Petroleum Limited), by annual trapping. 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. Some of the fauna monitoring has now been contracted externally but DEC staff are now present on the island (since 2010) and are actively involved and regularly consulted.

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). 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. Over the last five years (2006-2011) DEC has adopted a cohesive approach to regular monitoring and conducted an annual population census on Bernier and Dorre Island for all three species.

Captive breeding and reintroductions

As detailed in Appendix 1 a number of captive and reintroduced populations have been established or attempted for the western barred bandicoot, burrowing bettong and banded hare-wallaby, in WA, SA and NSW.

Captive groups provide animals for reintroductions, research and educational activities. Captive breeding of burrowing bettongs employing minimal husbandry has been very successful at Heirisson Prong, RTDBF, and Yookamurra and Scotia WS. More intensive captive breeding of western barred bandicoots at PCBC 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. RTDBF) due to the risk of avian predation (Friend and Beecham 2004), while intensive pen systems were more successful (e.g. PCBC) 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 better directed to managing reintroduction sites.

The reasons for previous re-introduction failures have been assessed and the results used to modify aspects for future re-introductions, including: site locations, site management, fence design, numbers of animals, method of release, and ongoing monitoring.

Details of the previous and current reintroductions attempts and captive breeding groups are provided in Appendix 1.

Disease management

Workshops on *Disease in Western Barred Bandicoot Populations* were hosted by DEC's WA Wildlife Research Centre in July 2002 and 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) provided a summary of evidence and symptoms of the diseases and future management and research directions in his report on the workshop.

Resulting actions undertaken from the workshops included:

- the preparation of a disease risk management strategy for future trapping, translocation and captive breeding work in WA (Chapman *et al.* 2008);
- the euthanasia of western barred bandicoots diseased animals held in captivity or at reintroduction sites
- the closure of the captive breeding colony at the PCBC;
- provision of the euthanased animals to Murdoch University for further research; and
- a halt to all future translocations of the western barred bandicoot from diseased populations, pending further research into the papilloma-like syndrome.

Recovery team meetings in 2005 and 2007, and a further symposium on western barred bandicoot research was held at Murdoch University in February 2007 to outline current conservation and research effort (Bennett 2007).

Completed research into disease includes:

- research into toxoplasmosis, at Murdoch University,

- investigation of the incidence of *Chlamydia* in western barred bandicoots on Dorre and Bernier Islands (Kutlin *et al.* 2007).
- investigations to identify the cause of the papilloma-like syndrome, by Murdoch University (Bennett *et al.* 2008; Woolford *et al.* 2007; Woolford *et al.* 2008)

The disease risk management strategy does not address the issue of possible spread of disease by members of the public visiting Bernier and Dorre Islands. This threat is being addressed as a new recovery action in the plan.

Fox control

Fox baiting techniques have been established by DEC with significant success. The *Western Shield* program (see section 2.1) includes fox baiting over an area of 3.5 million ha is ongoing. Sites relevant to shark bay marsupials which are covered by this program include Lorna Glen where translocations have occurred of burrowing bettong in 2010 and 2011.

Feral cat control

Studies on feral cat control include 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). The new cat baits, Eradicat®, are currently being considered for registration by the APVMA (Australian Pesticides and Veterinary Medicines Association). 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 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

A cross-cultural workshop was held at Yulara in September 1999 entitled *Biodiversity and the Re-introduction of Native Fauna at Uluru - Kata Tjuta National Park* (Gillen *et al.* 2000) to identify and discuss the issues surrounding the re-establishment of locally extinct fauna within the Uluru - Kata Tjuta National Park. This has led to the establishment of a predator-free enclosure and reintroduction of rufous hare-wallaby, with involvement of Anangu, the Mutijulu community, and Green Corps.

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 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 ARR (Arid Recovery Project 2002). They also assist 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). 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. 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 Landscape 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.

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.

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.

Population viability analysis

A population viability analysis was undertaken by Richards (2004), 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 that cat predation was the most significant factor influencing breeding age, survivorship and overall population viability (Richards 2004).

Genetic research

DEC conducted out-breeding 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). Western barred bandicoots from Bernier and Dorre Islands have been cross-bred by DEC and maintained at the RTDBF. An evaluation of the benefits and ethics of cross-breeding needs

to be made by DEC and additional stakeholders, prior to further implementation of hybridisation, as suggested by Spencer and Moro (2001). Burrowing bettongs from the two Shark Bay islands have been reintroduced at the ARR and Yookamurra WS, setting a precedent for future hybridisation at other sites. The population established at Lorna Glen is a product of animals sourced from Dorre Island and Barrow Island. University of Western Australia PhD student Felicity Donaldson is examining the level of genetic divergence between Bernier and Dorre Island burrowing bettongs (Donaldson and Vercoe 2008), to determine whether hybridisation of the two populations is acceptable. Results from this study are in preparation for publication and currently not available.

A genetic study of wild and reintroduced western barred bandicoots has revealed extremely low levels of genetic diversity in the wild Bernier and Dorre Island populations □ amongst the lowest ever recorded for marsupials (Smith and Hughes 2008). The reintroduced Heirisson Prong population has a similar level of genetic diversity to the source population (from Dorre Island), whereas the DFBB population exhibit 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 crossing of the two islands did not appear to result in an increase in the diversity of mitochondrial DNA (Smith and Hughes 2008). The reintroduced and captive populations of *P. bougainville* at Heirisson Prong and Peron Peninsula represent attempts to maintain the distinctiveness of historically isolated evolutionary lineages. Given the shallow divergence of the natural populations, the management emphasis should concentrate on maximizing diversity for reintroduction attempts without the fear of outbreeding issues or of disrupting local adaptations (Smith and Hughes 2008).

Recent DNA work 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 Nilsson (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 10 years or until this plan is replaced.

Long term recovery objectives

The long term objective of the recovery program is to undertake conservation actions which:

Ensure the survival and maintain or improve the status of the western barred bandicoot and Bernier and Dorre Island subspecies of the burrowing bettong and banded hare-wallaby and Barrow Island subspecies of the burrowing bettong based on the IUCN criteria 2001 extent of occurrence*.

* Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon, excluding cases of vagrancy. This measure may exclude discontinuities or disjunctions within the overall distributions of taxa (e.g. large areas of obviously unsuitable habitat). Extent of occurrence can often be measured by a minimum convex polygon (the smallest polygon in which no internal angle exceeds 180 degrees and which contains all the sites of occurrence) (IUCN, 2001).

The downgrading of the status of these three species to anything less threatened than 'Vulnerable' is unlikely within the next ten 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 and reintroduction;
3. threat abatement;
4. community involvement and education;
5. Recovery team to manage recovery actions

The success of the recovery plan will be measured through assessing whether the recovery actions have been successful in achieving the primary objectives.

Criteria for success:

- population estimates calculated from a five year moving average for each species on Bernier, Dorre, Barrow and Boodie Islands, do not fall below the minimum figure (Illustrated in Figure 5 this would be approximately 1000 for each species);
- within ten years translocations to at least 3 new mainland or island sites have been established for each species.

Criteria for failure:

- The population estimate calculated from a five year moving average for any species on any island falls below the minimum figure (Illustrated in Figure 5 this would be approximately 1000 for each species);
- less than three introduced mainland or island translocations are established within ten years for each species.

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

4.3. Recovery actions

The recovery team for the western barred bandicoot, burrowing bettong and banded hare-wallaby is currently managed by DEC. Annual meetings are held to evaluate the progress of the Recovery Plan, and to modify recovery actions where necessary. These are organised by DEC, with participation from DEC, AWC, ARP, ULCBPG, DENR and other organisations as appropriate.

Action 1: Protect the wild populations and their habitat

This action includes:

- a) Manage and monitor populations on Bernier and Dorre Islands, Faure Island, Boodie Island and Barrow Island Nature Reserve.

Tasks:

- protecting from threats such as: biosecurity incursions, foxes, cats and fire
- implementing the disease risk management strategy (Chapman *et al.* 2008)
- include a management strategy to address the disease risk to fauna by members of the public visiting Bernier and Dorre Islands

These tasks will be undertaken in accordance with the Shark Bay Terrestrial Reserves Management Plan 2000 – 2009 (Hancock *et al.* 2000) and Barrow Island Nature Reserve Interim Management Guidelines (CALM 1999a).

- b) Developing and implementing a cost-effective monitoring program for the wild island populations.

Tasks:

- Implement monitoring protocol includes:
 - monitor island populations yearly,
 - checking for signs of disease and condition,
 - use baseline data as reference for ‘early warning’ thresholds to indicate where population declines may be cause for concern and developing management actions should such an occasion arise
- report annually to the Recovery Team to facilitate adaptive management of the populations and their habitat

Responsibility: DEC, AWC, Chevron

Cost: \$111,060 Year 1, \$111,060 Year 2, \$113,513 Year 3, \$122,088 Year 4, \$118,793 Year 5

Priority: High

Completion date: Ongoing

Action 2: Maintain captive populations

This action includes:

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

The population of banded hare-wallabies at the PCBC is to be maintained as a source population for future reintroductions in WA, particularly to Dirk Hartog and Faure Islands, Lagoon Point enclosure, Big Lagoon, Shark Bay.

Responsibility: DEC

Cost: \$60,000 per year

Priority: High

Completion date: Ongoing

Action 3: Maintain existing reintroduced populations

This action includes:

- a) Maintain the reintroduced populations of burrowing bettongs at Heirisson Prong.

Tasks:

- maintain the fox and feral cat free-status of the peninsula
- monitor the reintroduced populations biannually

- b) Manage Heirisson Prong according to the *Heirisson Prong Community Biosphere Reserve Management Plan 1999-2004* (Short 1999b)

Tasks:

- manage Heirisson Prong according to the *Heirisson Prong Community Biosphere Reserve Management Plan 1999-2004* (Short 1999b)
- translocate additional animals from Dorre Island to increase genetic diversity.

In the event SBSJV cease support for this project, 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

- c) Maintain the reintroduced populations of western barred bandicoots and burrowing bettongs at the Arid Recovery Project (ARP).

Tasks:

- Maintaining fox, rabbit and cat-free status
- monitoring populations biannually by trapping, and more regularly by track transects.

Responsibility: ARP

Cost: \$30,000 per year

Priority: High

Completion date: Ongoing

- d) Maintain the reintroduced populations of western barred bandicoots, burrowing bettongs and banded hare-wallabies at Faure Island.

Tasks:

- manage Faure Island according to the *Faure Island Pastoral Lease Management Plan* (Australian Wildlife Conservancy 2002)
- monitor the populations at least biannually.
- Supplement the populations of all three species on Faure Island with additional stock from Bernier and Dorre Islands.

Responsibility: AWC

Cost: \$55,000 per year

Priority: High

Completion date: Ongoing

- e) Maintain the reintroduced burrowing bettong population at Scotia Wildlife Sanctuary and Lorna Glen.

Tasks:

- Manage Scotia Sanctuary (Australian Wildlife Conservancy) and Lorna Glen.
- monitor the populations at least biannually.

Responsibility: AWC

Cost: \$25,000 per year

Priority: High

Completion date: Ongoing

- f) Maintain the reintroduced burrowing bettong population at Boodie Island and Lorna Glen.

Tasks:

- monitoring of the Boodie Island population every two years
- monitoring of the Lorna Glen population annually

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

Action 4: Reintroduce western barred bandicoots, burrowing bettongs and banded hare-wallabies to additional mainland and island sites

This action includes:

- a) Prepare and implement reintroduction proposals for Dirk Hartog Island National Park, Lagoon Point enclosure, Big Lagoon, Shark Bay for future mammal reintroductions.

Responsibility: DEC
Cost: \$85,000
Priority: High
Completion date: 2012 (Lagoon Point) TBC Dirk Hartog Island National Park

- b) Reintroduce burrowing bettongs at Yookamurra Wildlife Sanctuary.

Tasks:

- release burrowing bettongs into 1,100 ha enclosure
- monitor population 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

- c) Re-introduce western barred bandicoots, burrowing bettongs and banded hare-wallabies to additional mainland sites e.g. Lorna Glen, Lagoon Point enclosure, Mt Gibson Wildlife Sanctuary in WA, and Scotia WS and Uluru-Kata Tjuta National Park enclosure (western barred bandicoots and burrowing bettongs only).

Tasks:

- continue ongoing site management- maintain firebreak, burn external perimeter, maintain fence
- release captive bred or translocated animals
- monitor re-introduced animals annually
- exchange, where appropriate, of breeding animals with other captive populations to maximise genetic diversity.

Animals may be sourced from captive breeding centres or other reintroduction sites such as Barrow Island, Heirisson Prong, Arid Recovery Reserve or Faure Island. The reintroduced populations should be self-sustaining within five years of the first translocation.

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

Action 5: Conduct research to determine the genetic relationships of isolated populations of each species.

This action includes:

- a) Assess strategies for cross-breeding or hybridising of reintroduced populations to enhance genetic diversity.

Tasks:

- analyse results of previous hybridisation trials and genetic research (including tasks b and c) on each species, to determine whether the Bernier, Dorre and Barrow Island populations are genetically similar, or if combined genetic diversity is increased, without compromising local adaptation;
- use above analysis to determine whether cross-breeding or hybridisation is appropriate for each species;
- incorporate recommendations into recovery actions to manage re-introduced populations and to re-introduce species to new sites.

Responsibility: DEC, Recovery Team

Cost: \$8,000

Priority: Medium

- b) Ensure the publication of results of research into the taxonomic status and genetic structure of burrowing bettong populations.

This action involves continuing research into the genetics of burrowing bettongs to clarify the acceptability of separation at the subspecific level of the Shark Bay Island burrowing bettong populations from the Barrow Island population.

Responsibility: UWA, DEC, AWC

Cost: \$18,000 Year 1, \$8,000 Year 2

Priority: High

Completion date: 2012

Action 6: Enhance community participation and education in the recovery of western barred bandicoots, burrowing bettongs and banded hare-wallabies

This action involves:

- a) encouraging community involvement and ownership of the project and its achievements.

Tasks:

- Continue involvement of the Useless Loop community in the management of Heirisson Prong.
- Continue community involvement in the Arid Recovery Project.
- Support involvement of the Denham community in *Project Eden*.

Tasks:

- 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.
- re-establishing the *Project Eden* Community Advisory Committee or some similar community conservation group to maintain regular community and school education and

interaction activities, continuing TAFE and tertiary work placements and maintaining research collaborations and individual work experience programs.

Responsibility: ARP, Friends of the ARP, BHP Billiton ULCPBG, SBSJV, Wildlife Research and Management, DEC, WWF

Cost: \$7,500 per year

Priority: Medium

Completion date: Ongoing

Action 7: Manage recovery program.

This action includes:

- a) Organise Recovery team meetings.

Recovery team meetings are to be held at least biannually, with representatives from DEC, AWC, ARP, SEWPaC, Anangu people and other stakeholders as appropriate. Minutes of the meetings will be circulated to participants and stakeholders within two weeks of each meeting.

The recovery team will:

- regularly review success of recovery program in meeting recovery plan objectives;
- provide guidance on funding priorities;
- provide an avenue for updates on each project and knowledge exchange;

Responsibility: DEC

Cost: \$5,000 per year

Priority: High

Completion date: Ongoing

4.4 Implementation

The recovery program is currently supported by the input of staff and resources from DEC, AWC, SBSJV, ULCPBG, ARP and Chevron. Estimated costs of recovery actions for the first three years are shown in Table 5. Costs have been calculated at 2007 prices and will be revised for new projects as they arise. 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 Caring for Our Country, Lotterywest and private or corporate sponsors.

Table 5: Implementation costs

Action	Description	3 Year Cost \$	5 Year Cost \$	10 Year Cost \$	Responsibility	Completion Date
1	Protect existing wild populations and habitat					
	Bernier and Dorre Island management	84,000	140,000	280,000	DEC	Ongoing
	Monitor Bernier and Dorre Island populations	149,633	260,514	521,028	DEC	Ongoing
	Barrow Island management	18,000	32,000	64,000	DEC Chevron	Ongoing
	Monitor Barrow Island population	84,000	140,000	280,000	DEC Chevron	Ongoing
2	Maintain captive populations					

Action	Description	3 Year Cost \$	5 Year Cost \$	10 Year Cost \$	Responsibility	Completion Date
	Maintain PCBC	180,000	300,000	600,000	DEC	Ongoing
3	Maintain reintroduced populations					
	Maintain Heirisson Prong populations	150,000	250,000	500,000	ULCBPG SBSJV	Ongoing
	Maintain ARP populations	90,000	150,000	300,000	ARP	Ongoing
	Maintain Faure Island populations	165,000	275,000	350,000	AWC	Ongoing
	Maintain Scotia bettong population	75,000	125,000	250,000	AWC	Ongoing
	Maintain Boodie Island bettong population	90,000	150,000	300,000	DEC	Ongoing
4	Reintroductions to mainland and island sites					
	Reintroductions to Yookamurra WS, Uluru Kata-Tjuta National Park bettong population and other mainland sites	120,000	170,000		AWC , Parks Australia, DEC	Ongoing
5	Taxonomic and genetic research					
	Hybridisation strategies	8,000	8,000		DEC	Ongoing
	Publication of results of research into the taxonomic status and genetic structure of burrowing bettong populations	26,000	-	-	DEC, UWA, AWC	Ongoing
6	Enhance community participation and education					
	Useless Loop community participation	7,500	12,500	25,000	ULCBPG SBSJV WR&M	Ongoing
	ARP community participation	7,500	12,500	25,000	ARP Friends of ARP BHP	Ongoing
	Denham community participation	7,500	12,500	25,000	DEC WWF/TSN	Ongoing
	<i>Project Eden</i> /Faure Island ecotourism	7,500	12,500	25,000	DEC Shark Bay Shire	Ongoing
7	Secure ongoing funding					
	Recovery Team meetings	15,000	25,000	25,000	DEC	Ongoing
	Source additional funding	9,000	15,000		Recovery Team DEC	Ongoing

Action	Description	3 Year Cost \$	5 Year Cost \$	10 Year Cost \$	Responsibility	Completion Date
					ARP ULCBPG AWC	
8	Australia-wide interagency linkages	9,000	15,000	30,000	Recovery Team DEC AWC ULCBPG ARP	Ongoing
TOTAL		1,302,633	2,105,514	3,600,028		

4.5 Management practices and policies

Management practices include policies, strategies and broad guidelines that are not specific actions for the recovery of the threatened species, but provide guidance to avoid future impacts and contribute to the long-term conservation. For the threatened Shark Bay marsupials, strategies to avoid future impacts include:

- fire management policies
- quarantine procedures and restrictions relating to islands;
- recreation and visitor policies

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 involved should not be used further as a source for reintroductions until populations recover.

Only ‘disease-free’ populations of western barred bandicoots are to be used for translocation to reintroduction sites unless the significance of the disease is shown to be minimal, species specific, and the impacts manageable.

4.6 Guide for decision-makers

Under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) any person proposing to undertake actions which may have a significant impact on listed threatened species (including the threatened Shark Bay marsupials) should refer the action to the Minister for Environment. The Minister will determine whether the action requires EPBC Act assessment and approval. As these provisions relate to proposed (i.e. future) actions, they can include:

- actions which may result in increased impact from existing threat/s or potential threat/s; and
- actions which may result in a new threat.

Actions within areas of habitat critical for survival that could result in any of the following may result in a significant impact on Shark Bay threatened marsupial species:

- a major increase in numbers of feral cats or foxes in mainland sites or the introduction of these species to island sites;
- an increase in fire frequency or loss of habitat due to fire;
- introduction of novel weed species;
- introduction of disease to uninfected populations;
- any significant increase or acceleration of the effects of climate change; and

- change in land use to activities incompatible with conservation e.g. recreation and development.

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APPENDIX 1: TRANSLOCATION AND CAPTIVE BREEDING

Table 1: Re-introduction attempts

Species	Location	Source	Number acquired (date)	Population (date assessed)
Western barred bandicoot	Heirisson Prong	HPFBB/Dorre Island	14 (1995) 2 (1996)	Locally extinct (2008)
	Arid Recovery Reserve	Bernier Island	12 (#2001)	70-100 (2011)
	Faure Island	Heirisson Prong	20 (October 2005)	100 (2009)
Burrowing bettong	Heirisson Prong	Dorre Island	42 (1992-1995)	355 (2010)
	Yookamurra Wildlife Sanctuary	Bernier and Dorre Islands	10 (1995) 30 (1996) 2 (2001) 19 (2004)	65 (2007)
	Gibson Desert	Barrow Island	40 (1992)	0 (1993)
	Faure Island	Heirisson Prong	17 (2002)	800+ (2010)
	Arid Recovery Reserve	Bernier Island Heirisson Prong	10 (1999) 19 (2000)	2260 (2010)
	Boodie Island	Barrow Island	36 (1993)	200 (2011)
	Dryandra Woodland	RTD	23 (2003) 14 (2004)	0 (May 2005)
Banded hare-wallaby	Scotia WS	Yookamurra Wildlife Sanctuary	30 (2004) 90 (2005)	65 (2007)
	François Peron NP	PCBC	18 (2001)	0 (2002)
	Dirk Hartog Island	Dorre	21 (1978)	0 (1980)
	Faure Island	PCBC	52 (2004-2010)	Present numbers unknown (2010)

Bold groups are now considered self-sustaining populations

Data from Short *et al.* (1992), Short and Turner (2000), Richards and Short (2003), Arid Recovery (2004), C. Sims⁴, N. Thomas¹⁸, N. Marlow³, J. Richards¹⁵, J. Bentley⁹, J. Short¹⁶, K. Newport¹⁷ and K. Moseby⁶ (pers.comms.).

first released in 2000, but recaptured and quarantined at Adelaide Zoo, re-released 2001.

¹⁵ Dr Jacqueline Richards, Regional Ecologist, AWC, West Perth

¹⁶ Dr Jeff Short, Director, Wildlife Research and Management, Perth.

¹⁷ Karl Newport, Arid Recovery Project and BHP Billiton, Roxby Downs, South Australia.

Arid Recovery Reserve

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 km² conservation area in 2002 (Arid Recovery Project 2002). Numbers of animals trapped in 2005 were 277 bettongs and 35 bandicoots (K. Moseby⁶ pers. comm.). Additional burrowing bettongs were released into this area in 2008 and monitoring using transects and trapping have been implemented since then to monitor the population. High rainfall in 2010 contributed to a rise in burrowing bettong numbers and they are now found throughout 86 square kilometres of the reserve. Sixty square kilometres this area is free of feral cats, foxes and rabbits (Arid Recovery Project 2010).

Western barred bandicoots from Faure Island were released in Sept 2009 and are being monitored through trapping, track counts and scanning plates and are held within a soft release pen with water and supplementary feeding. At least two successful breeding events have occurred and this is encouraging, particularly prior to the approaching summer. It is planned to move independent progeny to a soft release pen in the Northern Expansion where western barred bandicoot numbers are low and habitat is suitable (Arid Recovery Project 2010).

Boodie Island

Burrowing bettongs from Barrow Island were translocated in 1998 by DEC, after their accidental eradication during a rat baiting campaign (Morris 2002). The population quickly established, with an estimate of over 200 animals in 2000 (K. Morris¹⁰ pers. comm.). The island is free from introduced predators.

Dirk Hartog Island

Banded hare-wallabies were reintroduced to Dirk Hartog Island 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).

Dryandra Woodland

Burrowing bettongs were released in spring 2003 and autumn 2004, as recommended by Friend *et al.* (1995) and Thomas *et al.* (2003). 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. Thomas¹⁸ pers. comm.).

Faure Island

Twenty nine banded hare-wallabies were reintroduced in 2004, 2005 and 2006 by AWC and the population appears to be increasing, with an estimate of 52 animals on the island (A. Dugand¹⁹ pers. comm.).

Burrowing bettongs from Heirisson Prong, were reintroduced in 2002 (Parsons *et al.* 2002a), and are well-established, with over 350 burrowing bettongs captured throughout the island during the annual monitoring in September 2010 (J. Short¹⁶ pers. comm.).

Twenty western barred bandicoots were reintroduced from Heirisson Prong in October 2005

¹⁸ Neil Thomas, Research Scientist, Department of Environment and Conservation, WA.

¹⁹ Alison Dugand, South West Regional Manager, AWC, Karakamia Wildlife Sanctuary, Chidlow, WA.

Francois Peron National Park

A reintroduction attempt of banded hare-wallabies to Peron Peninsula at Shark Bay in 2001 failed due primarily to cat predation (Morris *et al.* 2004; Hardman 2006). Plans to reintroduce a range of threatened mammals at the site have been modified with the creation of the Lagoon Point Enclosure at Big Lagoon, effectively an island has been created and banded-hare wallabies from PCBC are the only species to be translocated to the Lagoon Point Enclosure (Mawson 2004; Morris *et al.* 2004).

Gibson Desert

Burrowing bettongs were 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).

Heirisson Prong

The burrowing bettong population was established on the 1,200-hectare peninsula, and a subset of animals housed within an eight-hectare predator-free refuge between 1992 and 1998 (Short and Turner 2000). Heirisson Prong: Burrowing bettongs were reintroduced from Dorre Island between 1992 and 1995 (in three separate releases) (Short *et al.* 1994; 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 fluctuations also led to supplementation of the population with the return of 17 animals transferred to Faure Island in 2002. This occurred in October 2005. 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.

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.

Mortality of reintroduced western barred bandicoots at Heirisson Prong appeared high: 37% of animals released to free-range were not captured after the first month, 39% of young recruited 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). Movement away from the trap lines 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).

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 km² 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.

Lorna Glen

Lorna Glen is a former pastoral property located approximately 1100 km north-east of Perth (150 km north-east of Wiluna) in the North East Goldfields pastoral zone. It was purchased by the WA Government in 2000 for addition to the nature conservation estate and is now jointly managed by the Department of Environment and Conservation (DEC) and traditional owners. Lorna Glen covers 244,000 ha and straddles the Gascoyne and Murchison IBRA Regions. Recent biological surveys indicate that 13 species of mainly small mammal still persist on Lorna Glen. Historic records, knowledge of species' former distributions and sub-fossil surveys suggest that another 17 species of non-volant mammals.

Scotia Wildlife Sanctuary

After improving the perimeter fence around a 4,000-hectare section of Scotia WS, AWC reintroduced burrowing bettongs, using animals from Yookamurra WS, on four separate occasions (total 120) 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. Bentley⁹ pers. comm.). A survey in 2011 using transects and distance sampling analysis provided a population estimate for the burrowing bettongs of 250 (CI 134-444).

Uluru - Kata Tjuta National Park enclosure

Anangu and Parks Australia have constructed a 170 hectare feral proof enclosure in the Uluru-Kata Tjuta National Park. The building of the enclosure was a joint project between Department of Environment and Water Resources, Parks and Wildlife Commission of the Northern Territory and the Mutitjulu Community. Assistance in consultation with Anangu was provided by the Central Land Council. The construction commenced in April 2004 and was completed in September 2005.

Yookamurra WS

Reintroductions of burrowing bettongs from Bernier Island between 1995 and 2004 by Earth Sanctuaries Ltd. and AWC to the 1100 ha enclosure failed due to cat and fox predation and poor predator-proof fencing (J. Bentley⁹ pers. comm.).

Historic reintroduction

In 1924 there was an attempt to re-introduce burrowing bettongs from the Lake Phillipson area of SA to Kangaroo Island (Finlayson 1958).

Table 2: Captive* groups

Species	Location	Source	Number acquired (date)	Population assessed (date)
Western barred bandicoots	PCBC	Bernier Island	30 (1998)	0 (2005)
	RTD	PCBC & Kanyana	27 (1999)	0 (2008)
	ARR	PCBC & Faure Island	38 (2000-2009)	Unknown -numbers not available
Burrowing bettong	Lorna Glen	Barrow Island	65 (2010)	120 (2011)
		RTD	95 (2010)	
		Trimouille Island	34 (2011)	
	Scotia	Yookamurra	16 (1997-2000)	0 (2006)
Banded hare-wallaby	PCBC	Bernier	31 (1998-2010)	25 (2011)
	RTD	Dorre	18 (1998)	0 (2008)

Data from N. Thomas¹⁸, N. Marlow³, K. Moseby⁶, A. Dugand²², J. Bentley⁹, J. Short²⁰, and C. Sims⁴ (pers.comms.), Arid Recovery Project (2001), and Mawson (2004).

RTD = 'Return To Dryandra' Field Breeding Facility, PCBC = Peron Captive Breeding Centre, HPBE = Heirisson Prong Breeding Enclosure.

*"Captive" refers to confined in fenced enclosures

Dryandra Field Breeding Facility (RTD)

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 no banded hare-wallabies remain.

Peron Captive Breeding Centre

DEC's PCBC 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 remaining western barred bandicoots held at the PCBC 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. Butcher⁷ pers. comm.).

Yookamurra Wildlife Sanctuary

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