RUFOUS HARE-WALLABY
(*Lagorchestes hirsutus*)
NATIONAL RECOVERY PLAN

Wildlife Management Program No. 43

Australian Government

Department of Environment and Conservation
Our environment, our future

Northern Territory Government

WESTERN AUSTRALIAN WILDLIFE MANAGEMENT PROGRAM NO. 43

RUFOUS HARE-WALLABY RECOVERY PLAN

Prepared by

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Cover photograph of the rufous hare-wallaby by Judy Dunlop.

FOREWORD

Recovery Plans are developed within the framework laid down in Department of Environment and Conservation Policy Statements Nos 44 and 50.

Recovery Plans outline the recovery actions that are required to address those threatening processes most affecting the ongoing survival of threatened taxa or ecological communities, and begin the recovery process.

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 (Appendix 1).

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 2012.

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ACRONYMS

- ASDP Alice Springs Desert Park, NRETAS
- AWC the Australian Wildlife Conservancy
- ARAZPA Australasian Regional Association of Zoological Parks and Aquaria
- CLC the Central Land Council
- DEC the WA Department of Environment and Conservation
- DEH SA Department for Environment and Heritage, South Australia (now DENR Department of Environment and Natural Resources)
- DSEWPAC the Commonwealth Department of Sustainability, Environment, Water, Population and Communities, Parks Australia Division,
- NRETAS the Biodiversity Conservation Unit of the NT Department of Natural Resources Environment, Arts and Sport (formerly Parks and Wildlife Commission of the Northern Territory)
- ZAA the Zoos and Aquaria Association (formerly ARAZPA)

SUMMARY

***Lagorchestes hirsutus* ssp., mala or rufous hare-wallaby (unnamed central mainland subspecies).**[1]
***Lagorchestes hirsutus bernieri,* rufous hare-wallaby (Bernier Island).**
***Lagorchestes hirsutus dorreae,* rufous hare-wallaby (Dorre Island)**

Family: Macropodidae
DEC Region: Midwest, Pilbara
DEC District: Shark Bay, East Pilbara
Shire: Shark Bay, East Pilbara
Recovery Team: Mala Recovery Team (Appendix 1)
Current status (EPBC Act): *L. hirsutus* ssp. (unnamed subsp.) Endangered
L. h. bernieri Vulnerable
L. h. dorreae Vulnerable
Habitat requirements: Dense heath and shrub cover or *Triodia* grasslands

Distribution
The mala was formerly distributed across Australia within the spinifex deserts of the Northern Territory and north-west South Australia and is now extinct in the wild on the mainland. There is a single introduced population on Trimouille Island off the Pilbara coast of Western Australia that has been self-sustaining for over eight years. The remaining populations are held in captivity in the Northern Territory (Watarrka National Park, Alice Springs Desert Park, Uluru-Kata Tjunta National Park [UKTNP]), Western Australia (Peron Captive Breeding Facilities, Lorna Glen), and New South Wales (Scotia Sanctuary).

The Bernier Island and Dorre Island rufous hare-wallaby subspecies (Shark Bay islands subspecies) occur only on Bernier and Dorre Islands in Shark Bay, Western Australia.

The south-west subspecies (*Lagorchestes hirsutus hirsutus*) formerly inhabited the temperate woodlands and grasslands of Western Australia and is now extinct.

Threats
The mala is thought to have disappeared due to a combination of predation by introduced species (the European fox *Vulpes vulpes* and feral cat *Felis catus*), habitat destruction and alteration due to agriculture and pastoral use, the impact of the introduced European rabbit *Oryctolagus cuniculus*, and changes in fire regimes. The populations of the rufous hare-wallaby on Bernier and Dorre Islands are stable, but are potentially threatened by the introduction of exotic species, fire and disease.

Recovery actions
1. Protect and monitor the Shark Bay islands populations and their habitat;
2. Maintain captive mala populations;
3. Maintain and monitor the Trimouille Island mala population;
4. Reintroduction of the mala to mainland and island sites;
5. Repeat a population viability analysis (PVA);
6. Research the taxonomic status and genetics;

[1] Listed under EPBC Act as *L. hirsutus* ssp. (unnamed subsp.)

7. Improve community participation and education; and
8. Coordinate the Recovery Program.

Cost for first five years
$1,863,000

2. SPECIES INFORMATION

2.1. Taxonomy and description

The rufous hare-wallaby was first described by Gould in 1844 from specimens obtained by John Gilbert in south-western Western Australia (Gould 1844). Four subspecies are recognised: *Lagorchestes hirsutus* 'undescribed central mainland subspecies' from the centre of Australia, *L. hirsutus bernieri* from Bernier Island, *L. hirsutus dorreae* from Dorre Island, and *L. h. hirsutus* from south-western Western Australia (Thomas 1907; Courtenay 1993; Maxwell *et al.* 1996). The common name of "mala" used by Indigenous Australians of the western deserts region (Johnson and Burbidge 1995; Burbidge *et al.* 1999) is used to refer to *L. hirsutus* undescribed central mainland subspecies.

The rufous hare-wallaby is one of the 'true' hare-wallabies. It is one of the smaller macropods, which, like all the hare-wallabies, received its name from its supposed resemblance to the hare (Strahan 1995) and the rufous colour of their long, soft fur (Johnson and Burbidge 1995). The fur has a "rich sandy buff" colouration, and the length increases towards the lower back, giving the animals a "shaggy" appearance from which the specific name *hirsutus* is derived (Troughton 1967; Johnson and Burbidge 1995; Lundie-Jenkins and Moore 1996). The species is rabbit-sized, has an average weight of 1750 g and there are no significant differences in body weight, head/body length or several other body measurements between the sexes (Richards *et al*. 2001).

The Shark Bay islands subspecies are larger than the mala, and have a shorter tail (Johnson and Burbidge 1995). Dorre Island animals have a shorter pes and tail and longer head than animals on Bernier Island (Richards *et al*. 2001). Bernier Island animals have shorter ears and are paler in colour, while Dorre Island animals are redder in colour and their skulls are narrower between the orbits than the mala (Troughton 1967). This was the basis for supporting the original separation of the Shark Bay islands subspecies (Thomas 1907).

2.2. Distribution

Rufous hare-wallabies (*L. h. hirsutus* (extinct) and mala) were once distributed through much of the western half of mainland Australia, including the interior of Western Australia, northern South Australia, and central and southern Northern Territory (Johnson and Burbidge 1995; Figure 1). Finlayson (1961) described the distribution as "fluctuating and discontinuous and with isolated colonies widely sundered", suggesting that the distribution had declined already.

Two small populations of rufous hare-wallabies remained in the Tanami Desert in the Northern Territory until the late 1980s, surviving in areas characterised by a tight mosaic of vegetation in various stages of fire succession, including areas of burnt and unburnt spinifex (Bolton and Latz 1978). One population was destroyed by a fox in 1987 and the other by wildfire in 1991 (Gibson *et al.* 1994b). Extensive ground and aerial surveys through areas of the Northern Territory and Western Australia failed to locate additional populations (Gibson 1986; Burbidge and Pearson 1988).

The only surviving animals from these wild populations are now housed in captivity (Watarrka and Uluṟu - Kata Tjuṯa National Parks and Alice Springs Desert Park in the Northern Territory and the Peron Captive Breeding Centre within François Peron National Park in Western Australia, and Scotia Sanctuary in New South Wales) or have been translocated to a secure site on 520 ha Trimouille Island in the Montebello Islands Conservation Park off the Pilbara Coast in Western Australia (Langford and Burbidge 2001). Reintroduction attempts of the undescribed central mainland subspecies to the Tanami Desert in the Northern Territory (Gibson *et al.* 1994a,b) and to François Peron National Park in Shark Bay were not successful (Morris *et al.* 2004; Hardman 2006).

The Shark Bay islands subspecies have survived as wild populations on Bernier and Dorre Islands Nature Reserves (Class A Reserve No 24869; Figure 2) vested in the Conservation Commission of Western Australia, in Shark Bay (Hancock *et al*. 2000). Day use of Bernier Island is permitted, however overnight recreational use is prohibited, and Dorre Island is a 'prohibited area' with access by permission only (Hancock *et al.* 2000). Populations on Bernier and Dorre Islands were estimated at approximately 3,100 and 3,200 respectively by Short *et al.* (1997b). Substantial fluctuations in numbers, presumably due to rainfall, were observed in surveys conducted three years apart (Short *et al.* 1997b). There are no captive populations of Bernier or Dorre Island stock and none have been reintroduced. Eldridge *et al.* (2004) have recommended that the populations be left to "muddle on" and not be used for reintroduction due to the lower levels of genetic diversity present within the populations, compared with mainland stock.

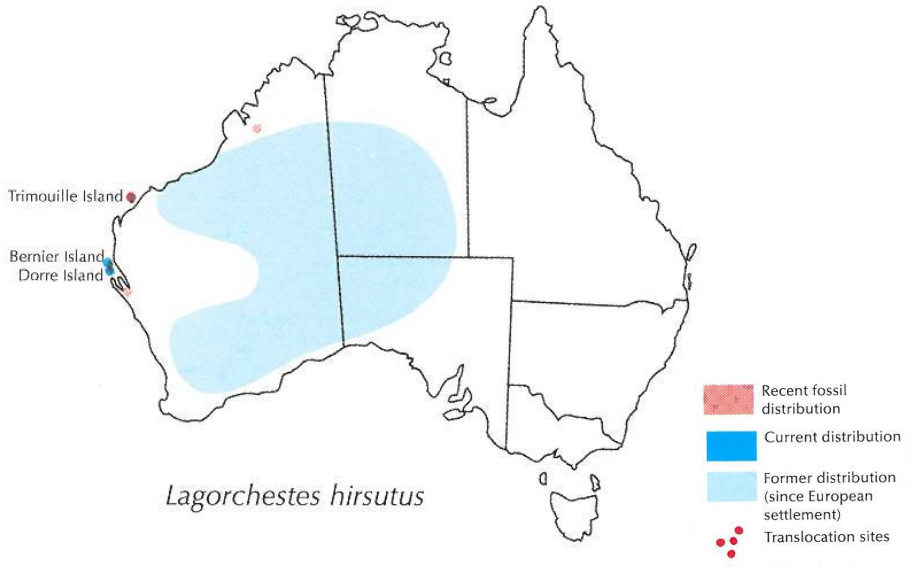

Figure 1: Past and present distribution of the rufous hare-wallaby (adapted from Strahan 2008, including historical and sub-fossil records). Introduced and captive populations are displayed in Figure 3.

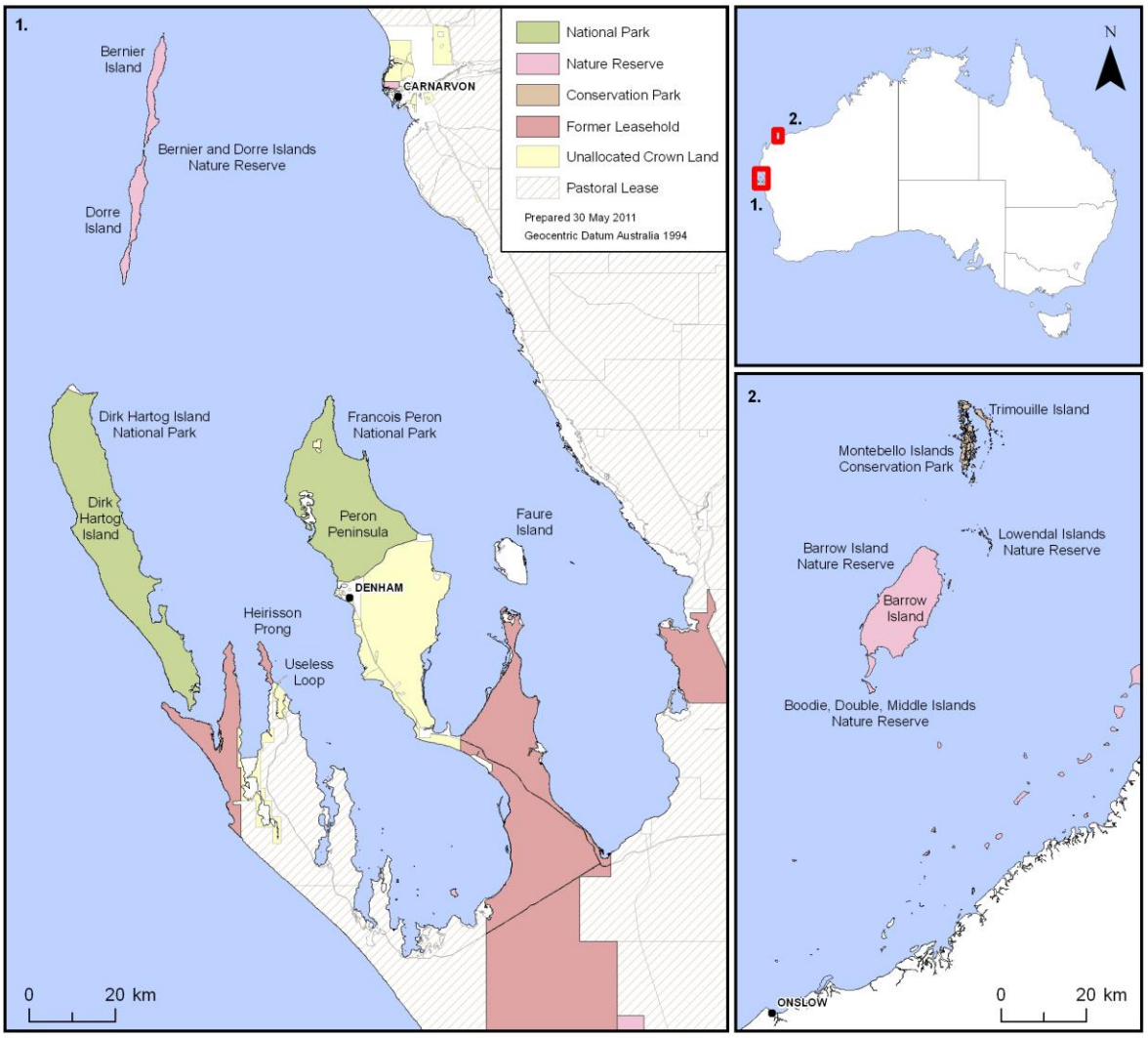

Figure 2: (1.) Shark Bay, Western Australia, showing the location of Bernier, Dorre, Dirk Hartog and Faure Islands, Denham and Peron Peninsula (François Peron National Park). (2.) Trimouille Island, Pilbara, northwest coast, Western Australia. Inset shows the location of Shark Bay and Trimouille Island.

2.3 Status of populations

All populations of the rufous hare-wallaby are considered important populations. The wild populations of rufous hare-wallabies that reside on Bernier and Dorre Islands Class A Nature Reserve in Shark Bay are significant to the long-term survival and recovery for the species. Bernier Island is approximately 44 km^2 and Dorre Island 53 km^2. There were estimated to be 4300 - 6700 rufous hare-wallabies on Bernier and Dorre Islands combined, depending on conditions of drought or average rainfall respectively (Short and Turner 1993; Short *et al.* 1997b). More recently, global detection functions have been applied to monitoring data 2006-2010 from these islands. Five year averages are for Bernier Island 642 and Dorre Island 1301 with a global estimate of 1868 (CI 1043-3033) (Table 1). These estimates are lower than those estimated previously for these islands. The population fluctuations appear to closely follow average rainfall trends (Figure 3).

Table 1: Population estimates of rufous hare-wallabies, Shark Bay, Western Australia modelled using global detection functions with upper and lower confidence intervals.

Survey year	**2006**	**2007**	**2008**	**2009**	**2010**	**5-year average**
Bernier upper CI	1518	266	681	705	2285	**642**
Bernier estimate	720	148	542	453	1346	
Bernier lower CI	324	48	402	176	813	
Dorre upper CI	2064	883	1996	2315	3779	**1301**
Dorre estimate	1584	419	1219	1457	1827	
Dorre lower CI	1133	139	714	744	532	
Global upper CI	3287	988	2648	3087	5157	3033
Global estimate	**2217**	**531**	**1729**	**1878**	**2985**	**1868**
Global lower CI	1266	229	1096	1051	1575	1043

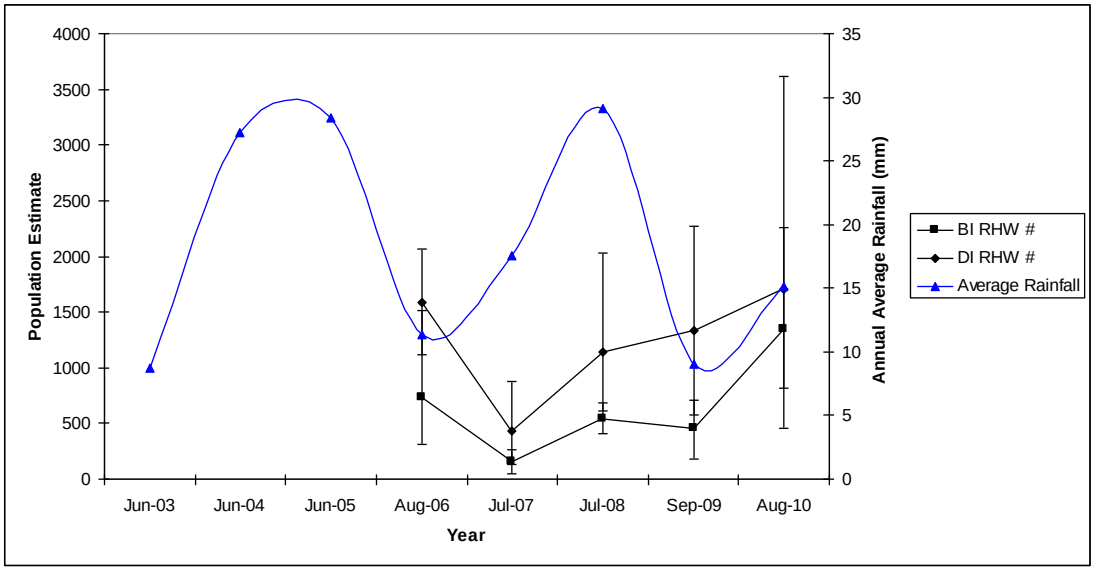

Figure 3: Monitoring data with global detection functions applied to produce population estimates of rufous-hare wallabies on Bernier and Dorre Island with average rainfall trend indicated.

The two island populations represented the only remaining wild populations of the species, until the recent successful introduction to Trimouille Island of a selected group of the mala, which has been extant for over ten years (Figure 4). The current number of mature individuals is unknown, however monitoring by track and dropping searches between 2000 and 2004 has suggested that the population is flourishing, with tracks throughout the island (A. Burbidge[5] personal communication).

There have been no reintroductions of the Shark Bay islands subspecies to the mainland or islands, and no animals from these subspecies are held in captivity. Conservation of these two island wild populations is therefore essential to the survival of these subspecies. The introduced mala population on Trimouille Island in Western Australia (Table 2), and other mala held in captivity at a variety of locations (Table 3), are also regarded as significantly important for the maintenance of genetic diversity within the species (Eldridge *et al.* 2004).

Table 2: Summary of introductions and reintroductions of the mala. Data include the recent minimum population size (numbers trapped) and are from Short *et al.* (1992), Gibson *et al.* (1994b), Burbidge *et al.* (1999), Langford (1999), Langford and Burbidge (2001), Morris *et al.* (2004), Hardman (2006) and A. Burbidge[2], C. Pavey[3], J. Clayton[4]and C. Sims[3] (personal communication). *Estimate only from track and dropping searches (no trapping). CBC = Captive Breeding Centre.

Location	Original source	Number released (date)	Population (date assessed)
Lake Surprise, Tanami	Tanami Desert (via AZRI)	27 (1984-85)	0 (1986)
Lake Surprise, Tanami	Tanami Desert (via AZRI)	81 (1990-92)	0 (1993)
Sangster's Bore, Tanami	Tanami Desert (via AZRI)	51 (1989-1993)	0 (1994)
Trimouille Island	Tanami 'Mala Paddock'	30 (1998)	>120* (2004)
François Peron National Park	Tanami 'Mala Paddock' (via Peron CBC)	16 (2002)	0 (2004)

Table 3: Summary of source, translocations and recent minimum population size (number trapped) of current captive breeding populations of mala. Data from Langford and Burbidge (2001), Hardman and Moro (2006a,b), A.A. Burbidge[5], N. Thomas[6], N. Marlow[7], J. Bentley[8], and C. Sims[3] (personal communication). ASDP = Alice Springs Desert Park, AZRI = Arid Zone Research Institute, CBC = Captive Breeding Centre, FBF = Field Breeding Facility.

Location	Original source	Number acquired (date)	Total population (date assessed)
Watarrka National Park	Tanami 'Mala Paddock' Tanami 'Mala Paddock' AZRI	72 (2000) 18 (2001) 6 (2001)	200 – 250 (2006)
Scotia Sanctuary	Tanami Desert (via AZRI, ASDP, Monarto Zoo)	6 (2001) 19 (2004)	30 (2006)
ASDP	Tanami Desert (via AZRI)	46 (1997)	8 (2007)
Peron CBC	Tanami Desert	29 (1999)	21 (2011)
Dryandra FBF	Tanami Desert	19 (1998)	0 (2011)
Uluṟu-Kata Tjuṯa National Park	Tanami Desert (via Watarrka NP)	24 (2005)	105 (2011)

[2] Andrew Burbidge, Research Fellow, DEC, Perth.
[3] Chris Pavey, Threatened Species Manager, Biodiversity Conservation, NRETAS, NT.
[4] Jim Clayton, Reintroductions Officer, Natural and Cultural Resources Unit Uluṟu - Kata Tjuṯa National Park.
[5] Andrew Burbidge, Research Fellow, DEC Perth.
[6] Neil Thomas, Principal Technical Officer, DEC Perth.
[7] Dr Nicky Marlow, Senior Research Scientist, DEC Perth.
[8] Dr Joss Bentley, Regional Ecologist, AWC, Scotia Wildlife Sanctuary, NSW.

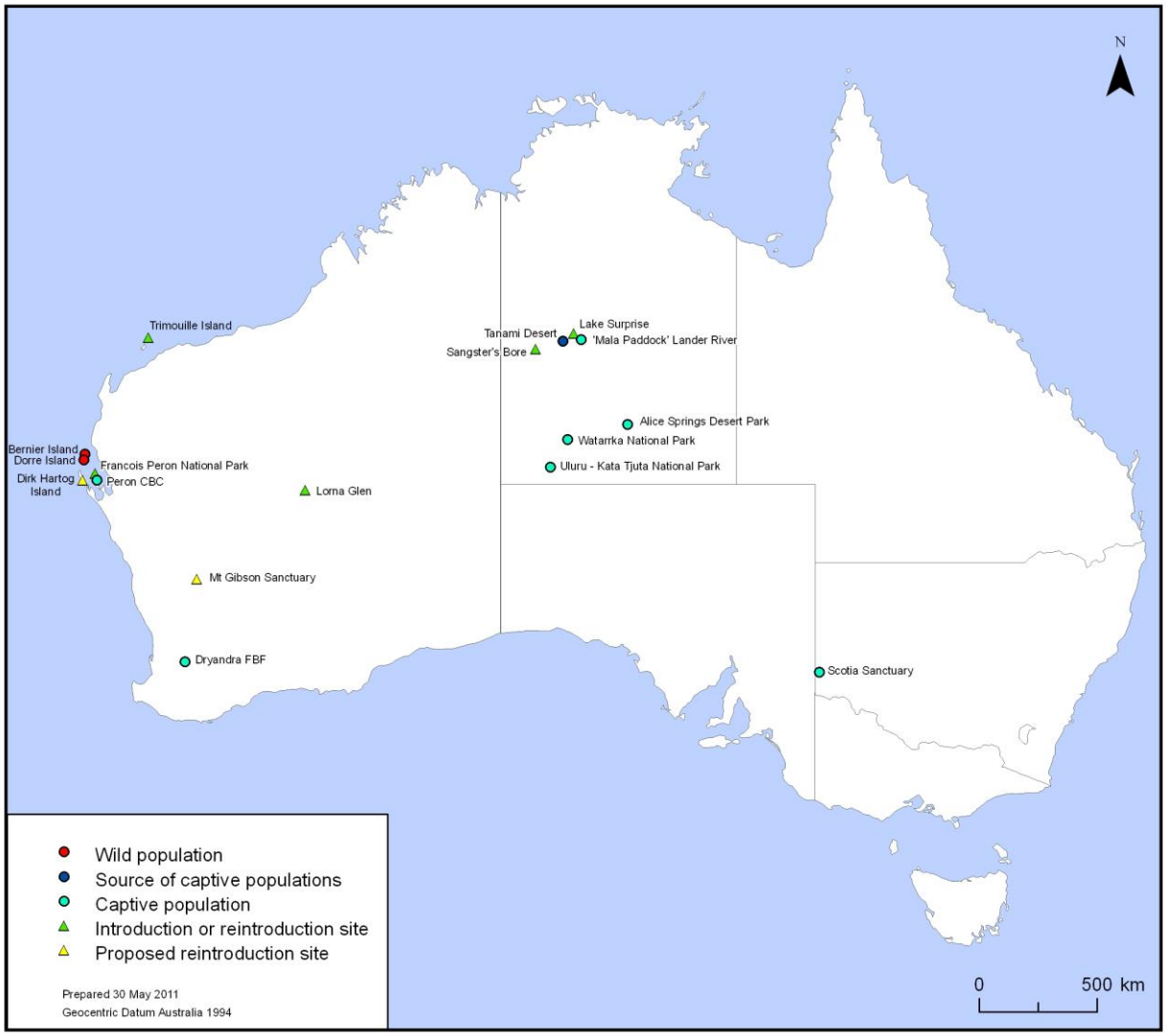

Figure 4: The location of current captive and introduced rufous hare-wallaby populations throughout Australia, and introduction and reintroduction sites (including proposed).

2.4 Habitat

John Gilbert (in Gould 1863) described collecting specimens of the rufous hare-wallaby from low scrub country, and Leake (1962) reported that the species occupied sandplain habitat in the shrublands and woodlands of semi-arid Western Australia. It occurred in mature *Triodia* grasslands in desert regions of central and Western Australia (Bolton and Latz 1978) and Aborigines were described as hunting rufous hare-wallabies through spinifex-mulga country, suggesting that the species may have occurred in a variety of habitats (Finlayson 1935). The species occupies all habitats throughout Bernier and Dorre Islands, including areas of heath, dune, *Triodia*, and travertine heath (Short and Turner 1992). Lundie-Jenkins (1989) found that habitat patchiness, spinifex hummock size, food diversity, and the degree of senescence of vegetation were influential in determining the distribution of rufous hare-wallabies in remnant populations in the Tanami Desert. A population of mala reintroduced into François Peron National Park in 2001 was shown to use dense shrub areas dominated by *Lamarchea hakeifolia* rather than adjacent areas supporting *Triodia plurinervata* (Hardman and Moro 2006a; Hardman 2006).

Habitat critical to the survival of the species

Habitat critical to the survival of the species includes the area of occupancy of important wild and translocated populations, potential habitats that present opportunities for reintroduction of the species within the next 10 years, and additional potential habitat sites which have predator control.

Habitat on Bernier and Dorre Islands is critical to the survival of the Shark Bay islands subspecies of the rufous hare-wallaby, which occupy all habitats throughout the islands (Short and Turner 1992). Trimouille Island, within the Montebello Islands Conservation Park, supports the only wild population of the mala and is critical to its survival in the wild.

Potential habitats that present opportunities for reintroduction of the species within the next 10 years include a number of sites managed for the conservation of other threatened species: Dirk Hartog Island National Park, Lorna Glen managed by DEC in Western Australia, and Mount Gibson Sanctuary (AWC). All these conservation sites have programs to control introduced predators, and represent locations thought to be within the past range of the mala.

The importance of fire in the creation of habitat mosaics may also be important in assisting with the choice of sites for mainland reintroductions of the rufous hare-wallaby to *Triodia* grasslands. Suitable areas of habitat would include those characterised by a mosaic of vegetation in various stages of fire succession, including areas of burnt spinifex offering food from plants regenerating after fire and unburnt spinifex offering refuge areas (Bolton and Latz 1978).

Habitat critical to the survival of rufous hare-wallabies is likely to include areas of dense heath and shrub cover in areas where introduced predators are absent. *Triodia* grasslands are thought to be important in the central desert region, and in particular, areas dominated by mature, but not senescent spinifex *Triodia pungens* (Bolton and Latz 1978). Species of plant other than *Triodia* spp. are likely to be important in areas in the southwestern Western Australia (Hardman and Moro 2006a).

2.5 Legislative status

The mala is listed nationally as 'Endangered' under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the Dorre Island and Bernier Island subspecies are both listed nationally as 'Vulnerable'.

The World Conservation Union (IUCN) lists the south-west mainland subspecies of the rufous hare-wallaby as 'Extinct', the mala as 'Endangered', and both the Dorre Island and Bernier Island subspecies as 'Vulnerable' (IUCN 2008), as does the *Action Plan for Australian Marsupials and Monotremes* (Maxwell *et al.* 1996). The extant island subspecies and rufous hare-wallaby are listed under 'Schedule 1' (Fauna that is likely to become extinct or is rare) in Western Australia, under section 14(4) of the Western Australian *Wildlife Conservation Act 1950.* The rufous hare-wallaby is described as 'Extinct in the wild' in the Northern Territory under the *Territory Parks and Wildlife Conservation Act 2000,* and 'Extinct' in South Australia under the *South*

Australian National Parks and Wildlife Act 1972. It was recently downlisted from 'Extinct in the Wild' in Western Australia due to the successful introduction to Trimouille Island (Table 4).

Table 4: Summary of species listing of the rufous-hare wallaby under State and Commonwealth legislation.

Species name	Population	Legislation	Conservation status
L. hirsutus bernieri	WA Shark Bay Bernier Island	*EPBC Act 1999* WA *WC Act 1950*	VU
L. hirsutus dorreae	WA Shark Bay Dorre Island	*EPBC Act 1999* (WA synonymised with *L. h. bernieri*)	VU
Lagorchestes hirsutus ssp (unnamed subsp.)	NT Central Mainland form	*EPBC Act 1999* WA *WC Act 1950* NT *PWC Act 2000* SA *NPW Act 1972*	EN EN EX (from the wild) EX

2.6 Biology and ecology

The ecology of the rufous hare-wallaby was studied in detail at Sangster's Bore in the Tanami Desert throughout the 1970s and 1980s by scientists from PWCNT prior to its extinction from the mainland, (Bolton and Latz 1978, Lundie-Jenkins 1993a, Lundie-Jenkins *et al.* 1993), and in captivity by Lundie-Jenkins (1993b,c). Scientific papers detailing the biology, distribution and abundance of rufous hare-wallaby on Bernier and Dorre Islands include Short and Turner (1992), Short *et al.* (1997b) and Richards *et al.* (2001). The reintroduction of the rufous hare-wallaby to the Tanami Desert was reported by Gibson *et al.* (1994b) and Lundie-Jenkins and Bellchambers (1994), to François Peron National Park by Morris *et al.* (2004), Hardman and Moro (2006a,b) and Hardman (2006) and the introduction to Trimouille Island by Langford and Burbidge (2001). Morphological and genetic information was published by Courtenay (1993) and additional genetic information by Eldridge *et al.* (2004).

Diet

Rufous hare-wallabies are predominantly herbivorous grazers and browsers, consuming forbs, perennial grasses, grass seed heads, seeds and bulbs of sedges, and some dicotyledonous plants such as *Neobassia astrocarpa* and *Frankenia* sp. (Pearson 1989; Lundie-Jenkins 1989; Lundie-Jenkins *et al.* 1993). In the Tanami Desert they had a highly variable diet, with leaf and stem material from monocots forming the staple diet, though seeds and succulent fruits were preferred during the short periods when they were available (Lundie-Jenkins *et al.* 1993). During drier periods they coped with a high-fibre diet of spinifex, and may also have consumed insects (Lundie-Jenkins 1989). Jarman (1984) regarded the species as seed head specialists.

Reproduction and development

Rufous hare-wallabies are polyoestrous and monovular (Lundie-Jenkins 1993c). They typically carry a single pouch young, but one incidence of twinning was recorded on Dorre Island (Richards *et al.* 2001). Pouch life of the rufous hare-wallabies averages four months, and while captive animals can produce up to three young per year, it is

probable that only one or two offspring are produced each year in the wild (Lundie-Jenkins 1993c).

The rufous hare-wallaby are regarded as continuous breeders under favourable conditions (Johnson and Burbidge 1995), with breeding interrupted by drought (Tyndale-Biscoe and Renfree 1987; Lundie-Jenkins 1989). Reintroduced animals in the Tanami Desert showed no seasonality of births but pouch young survival was influenced by rainfall and food quality (Lundie-Jenkins and Moore 1996). Limited information is available regarding the breeding season of rufous hare-wallabies on Dorre and Bernier Islands, and reintroduced rufous hare-wallabies in François Peron National Park were capable of breeding throughout the year (Hardman 2006). They carried pouch young from March to September and the incidence of young peaked in the winter months (77% of adult females carrying pouch young or lactating), declining in spring (71%) and autumn (18%) (Richards *et al*. 2001). Age at sexual maturity for reintroduced Tanami Desert animals ranged between 5 – 18 months for females and was approximately 14 months for males (Langford 2001). The smallest female carrying pouch young on Bernier and Dorre Islands weighed 1200 g and sexual maturity in males is likely to occur at about 1600 g (Richards *et al.* 2001).

Survival and longevity

Rufous hare-wallabies can survive and reproduce in captivity for at least eight years (Lundie-Jenkins and Moore 1996). Their life span in the wild is unknown.

Behaviour

Rufous hare-wallabies shelter during the day in small scrapes, half hidden beneath bushes or spinifex clumps (Shortridge 1909; Hardman and Moro 2006a). On Bernier and Dorre Islands they may use single-entrance burrows of about one metre in length and 30 cm depth (Short and Turner 1992). They tend to be solitary animals, however there was some evidence of social organisation within animals maintained in a captive colony (Lundie-Jenkins 1993b). The average home range of a small sample of rufous hare-wallabies reintroduced to François Peron National Park was 7 ha (Hardman 2006).

Disease

The Alice Springs Desert Park has recorded minor bacterial infections and fungal disease in captive rufous hare-wallabies and tuberculosis has been diagnosed in the species but was controlled by modification of husbandry practices (Langford 2001). Histological and immunohistological investigation of the lymphoid tissue of the rufous hare-wallaby revealed immunopathology consistent with bacterial infection (Young *et al.* 2003). No major viral diseases or toxoplasmosis have been recorded in the species.

Hardman (2006) found three endoparasite species (*Strongyloides* sp., *Entamoeba* sp. and *Eimeria* sp.) in rufous 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.

Tolerance to sodium monofluoroacetate (1080)

Mala were found to possess a high tolerance to 1080 poison, commonly used in the control of foxes and rabbits in Australia, particularly Western Australia (King 1988). Animals tested survived doses of up to 20 mg/kg of 1080, suggesting that rufous hare-wallabies should be at little risk from accidental poisoning during fox, cat, and rabbit control programs.

2.7 Known and potential threats

There appear to have been a common series of threats to the former mainland and the Shark Bay islands subspecies. These include predation by the introduced fox and feral cat, habitat alteration and grazing by rabbits and livestock, and changes in fire regimes (Maxwell *et al*. 1996).

The major threats to the island populations of the Shark Bay island rufous hare-wallabies, outlined in the *Shark Bay Terrestrial Reserves Management Plan 2000-2009* (Hancock *et al.* 2000), were:

- the introduction of exotic species, particularly foxes and feral cats, and also rabbits, rats, and mice;
- a major fire event;
- inappropriate recreation activity or development.

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

Taxon	Location of population	Threats
L. hirsutus bernieri	**WA** • Bernier Island	No immediate threats, potential threats include • Disease • Fire • Climate change (prolonged drought) • Inappropriate recreation or development • Introduction of herbivores
L. hirsutus dorreae	**WA** • Dorre Island	No immediate threats, potential threats include • Disease • Fire • Climate change (prolonged drought) • Inappropriate recreation or development • Introduction of herbivores
Lagorchestes hirsutus ssp (unnamed subsp.)	**WA** • Trimouille Island	No immediate threats, potential threats include • Disease • Fire • Climate change (prolonged drought) • Inappropriate recreation • Introduction of herbivores
Lagorchestes hirsutus ssp (unnamed subsp.)	**Mainland sites** **WA** • Lorna Glen • Peron Captive Breeding Facility	Introduced predators pose an immediate threats in some areas • Predation by foxes and cats and at some sites wild dogs e.g. Lorna Glen Climate change is a threat at all sites • prolonged drought • lack of food resources

	NT • Tanami Desert • Mala paddock • Lake Surprise • Sangster's bore • Alice Springs Desert Park • Watarrka National Park • Uluru - Kata Tjuta National Parks **SA** • Scotia Wildlife Sanctuary	

Introduced predators – the fox and feral cat

Foxes have long been recognised as a threat to native wildlife (e.g. Le Souef and Burrell 1926; Finlayson 1961), however the extent of their impact was not realised until recent studies such as those of Kinnear *et al.* (1988), Priddel (1989), Short and Turner (2000), Kinnear *et al.* (2002), and Short *et al.* (2002). The combination of wildfire and fox predation was responsible for the final demise of the wild Tanami Desert populations of the mala (Gibson *et al*. 1994b).

Cats hunt by sight and are accomplished "sit and wait predators" (Newsome 1995) in some habitats (Hilmer *et al* 2010). The most common items found in their diet in Australia are rabbits, small mammals and reptiles (e.g. Dickman 1996; Risbey *et al.* 1999; Paltridge 2002). They consume a wide variety of native and introduced mammals, and have been found to consume bandicoots, bettongs and hare-wallabies when available (Dufty 1991; Christensen and Burrows 1994; Short and Turner 2000; Priddel and Wheeler 2004; Hardman and Moro 2006b).

Feral cats were regarded as responsible for the failure of reintroductions of the rufous hare-wallaby in the Northern Territory (Gibson *et al.* 1994a) and at François Peron National Park in Western Australia. Short and Turner (2000) and Richards and Short (2003) regarded both introduced foxes and feral cats as the primary threats to reintroduced burrowing bettongs and western barred bandicoots at Heirisson Prong in Shark Bay. A number of threatened mammal reintroductions have failed in the arid zone due primarily to predation by cats (e.g. Short *et al.* 1992; Gibson *et al.* 1994a; Christensen and Burrows 1994; Southgate 1994; Morris *et al*. 2004; Hardman 2006). Burbidge and Manly (2002) found that the presence of both foxes and cats were correlated with the extinction of critical weight range mammals on Australian islands, but cats were associated with extinctions on the more arid islands only. Extinctions of mammals on arid islands with cats but no foxes include Dirk Hartog, Hermite, Trimouille, St Francis and Reevesby Islands (Burbidge and Manly 2002). The reintroduced mala population and the threatened rufous hare-wallaby populations on Bernier and Dorre Islands are extremely vulnerable to the introduction of feral cats.

Fire

Burbidge *et al.* (1988) suggested a possible link with the disappearance of critical weight range mammals from the central deserts and the timing of Indigenous Australians departing from the region, resulting in a change in fire regimes. Lundie-Jenkins (1989) suggested that the fire regime had changed from small fires occurring

throughout the year (traditional patterns of burning by Aborigines) to one dominated by infrequent, large, intense summer fires.

Changes in the mosaic of burnt and unburnt habitat due to changes in fire regimes have been implicated in the demise of the rufous hare-wallaby from the spinifex deserts of central Australia (Bolton and Latz 1978; Lundie-Jenkins 1989; Lundie-Jenkins 1993a). However, Short and Turner (1994) did not find any relationship between the scale of vegetation mosaic and the presence of fine-grained mosaics of early seral-stage vegetation mixed within climax vegetation on population parameters of burrowing bettongs, golden bandicoots *Isoodon auratus*, or northern brush-tailed possums *Trichosurus vulpecula arnhemensis* at Barrow Island in Western Australia. As a consequence, they thought that loss of habitat mosaic was unlikely to be an adequate explanation on its own for the mainland decline or extinction of these species. The persistence of rufous hare-wallabies on Bernier and Dorre Islands, with their very different fire histories, suggests that a fire mosaic is not important on islands (Short and Turner 1992). The combination of wildfire and fox predation was responsible for the final demise of the wild Tanami Desert populations (Gibson *et al*. 1994b).

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

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

The risk of fire on Trimouille Island is low, due to the lack of *Triodia* grassland, and separation of more densely vegetated areas by sand blows and sparsely vegetated dunes (Langford 1997). No wildfires have occurred on the island since nuclear testing occurred in the 1950s (Langford 1997).

While fire poses little risk to intensively managed captive populations (e.g. Alice Springs Desert Park), more extensively managed captive populations (e.g. Watarrka National Park, Scotia Sanctuary, Lorna Glen) are as much at risk of wildfire as those that occur in the wild. Appropriate management practices such as prescribed burning, firebreaks, and back-burning, are required to minimise that risk.

Introduced mammalian herbivores

Many studies have highlighted the detrimental impact of introduced herbivores (rabbits, sheep, cattle, horses, goats) on the Australian environment (e.g. Rolls 1969; Foran 1986; Payne *et al.* 1987; Friedel *et al.* 1990; Long 2003). Morton (1990) suggested that introduced herbivores, in particular the rabbit, played a significant role in the decline of mammals from the arid and semi-arid zone of Australia. He suggested that introduced herbivores had altered the vegetation so that refuge areas during periods of drought were no longer available. This habitat degradation, combined with the impact of introduced predators and changes in fire regimes in some areas, was thought to have increased the risk of local extinctions of native mammals.

There is no information available about interactions between hare-wallabies and rabbits. Despite these observations, where possible, rabbits should be controlled or eradicated to facilitate recreating past habitats and avoid the potential for intraspecific competition. Other introduced herbivores, including livestock (camels, goats, cattle, pigs, sheep and donkeys) have been implicated in widespread habitat alteration (Rolls 1969), however there is no evidence for direct competition with mala.

Disease

Shortridge (1909) reported the "sudden and unaccountable" disappearance of a number of species of mammal by 1880, thought to be caused by "some epidemic or disease", which "appeared to be a kind of marasmus". Richards and Short (1996) provided anecdotal evidence from Amy Crocker, an early resident of the Nullarbor, of some "strange virus" that had caused the extinction of the burrowing bettong prior to the introduction of foxes in the Nullarbor region. However, there are no data to implicate disease in the extinction of the mala.

In May 2000 symptoms of two disease entities were discovered in the wild western barred bandicoot population on Bernier Island, and captive populations at Kanyana Wildlife Rehabilitation Centre, the Peron Captive Breeding Centre and the Dryandra Captive Breeding Facility. While neither of the conditions (a papilloma-like syndrome, expressed in the presence of wart-like growths and lesions, an ocular disease that was correlated with positive tests for a variety of types of *Chlamydia*; Sims 2002) were found in the wild rufous hare-wallaby (Shark Bay islands subspecies) (C. Sims[3] personal communication).

As a result of the disease entities, disease risk and hygiene guidelines for future trapping, translocation and captive breeding work in Western Australia, with particular attention to the island populations, have been produced by DEC (Chapman *et al.* 2008). The extent of the threat of disease is unknown however diseases in native wildlife can contribute to poor population health and reduced fertility. Extinctions caused by disease are often difficult to diagnose, as diseases do not usually leave conspicuous numbers of dead and dying animals (Caughley and Gunn 1996).

Toxoplasmosis is an infectious disease caused by the one-celled protozoan parasite *Toxoplasma gondii*. Cats are the only known definitive hosts of this parasite (Johnson *et al.* 1988), which is common in marsupials as both a subclinical infection and an overt disease (Munday 1978). For example, toxoplasmosis is prevalent in wild populations of eastern barred bandicoots (Obendorf and Munday 1990), and

macropods in South Australia (Johnson *et al.* 1988). Dickman (1996) suggested that declining populations of native wildlife should be screened to determine whether toxoplasmosis currently has serious deleterious effects. Recent research by Peter Adams from Murdoch University has suggested that toxoplasmosis is not prevalent in the native mammal fauna of Shark Bay (P. Adams[9], personal communication) and there have been no concerns raised as to the health of rufous hare-wallabies. There are no major disease issues with current captive populations (C. Pavey[6] personal communication and Section 1.4 above).

Climate Change

Drought is known to interrupt breeding in rufous hare-wallabies (Tyndale-Biscoe and Renfree 1987; Lundie-Jenkins 1989) and a temporary decline in abundance was observed in recent years in the Shark Bay islands populations following severe drought. If drought is prolonged food resources may become limited and breeding disrupted leading to population decline.

Inappropriate recreational activities or development

The threats (e.g. increased risk of fire, introduction of foxes, cats, dogs) associated with inappropriate recreational activities, development, or management practices on either the wild or reintroduced populations of the rufous hare-wallaby are minimised under current management guidelines outlined in the *Shark Bay Terrestrial Reserves Management Plan 2000 – 2009* (Hancock *et al.* 2000) and the *1996 Action Plan for Australian Marsupials and Monotremes* (Maxwell *et al.* 1996). Recreational and tourism activities tend to be permitted and managed in the Watarrka and Uluru - Kata Tjuta National Parks and Shark Bay region in a "manner compatible with conservation and other goals," to minimise environmental impacts (Hancock *et al.* 2000, p. 39).

Hancock *et al.* (2000) regarded any permanent structures, such as island-based tourism facilities (e.g. jetties, airstrips, accommodation), that would likely facilitate increased visitation to the island and thereby increase the biosecurity and fire risks, as incompatible with the high conservation values of Bernier and Dorre Islands. Developments at reintroduction sites such as Watarrka, Uluru - Kata Tjuta and François Peron National Parks, may be compatible with community participation, ecotourism and public education where appropriate actions are taken to minimise environmental impacts.

Populations under threat

The Shark Bay islands subspecies are potentially threatened by the introduction of exotic predators and fire. Captive populations of mala stock have been established in enclosures (Table 2). Threats to the captive populations include: introduction of predators, wildfire and failure of security fencing that allows captive animals to escape.

The long-term security of any reintroduced mainland populations is uncertain due to the difficulty in ensuring effective control of introduced predators in the long-term. The introduced population at Trimouille Island is potentially more secure due to the

[9] Peter Adams, PhD Student, School of Veterinary Science, Murdoch University

lack of introduced predators and lower chance of invasion. However the threats affecting or potentially affecting this population are prolonged drought and severe storms/cyclones. Continuity of management direction and the provision of resources in perpetuity are important considerations in the long-term viability of any reintroduced population, particularly those on the mainland.

3. RECOVERY PROGRAM

3.1 Previous and existing conservation measures

Also refer to Appendix 2

Recovery Team and planning

The rufous hare-wallaby recovery team was established in 1993. During the implementation of the Mala 2000-2004 recovery plan, the participants included NRETAS, WA DEC, Alice Springs Desert Park, Parks Australia and DSEWPaC. Meetings occurred annually to review progress and modify actions in the Recovery plan as required.

Monitoring of wild populations

Systematic monitoring of the Shark Bay islands subspecies was undertaken by CSIRO, on Bernier and Dorre Islands in 1988 and 1989 and repeated three years later (Short and Turner 1992; Short *et al.* 1997b). Maxwell *et al.* (1996) and Langford (2001) recommended that monitoring of the Shark Bay islands subspecies be carried out every three years. DEC held a workshop on monitoring regimes for the threatened mammals on Bernier and Dorre Island in 2003, with participants from DEC, CSIRO and AWC. The consensus was that more regular monitoring was important. Since that DEC has undertaken systematic monitoring annually in 2006-2011.

Introduction and reintroduction

Introduction of mala into sanctuaries that are fenced to exclude predators have been successful at most mainland sites e.g. Scotia Wildlife Sanctuary, South Australia and Watarrka National Park and Lander River, Northern Territory with self-sustaining populations being established at these sites in the last few years. Additionally, the population introduced onto Trimouille Island, WA continues to persist. The reintroduction of mala to Lorna Glen, W.A. failed due to predation by cats and wild dogs. Reintroductions are planned for Dirk Hartog Island National Park, WA, once feral predators have been eradicated.

Captive breeding

2000 Work began on an enclosure at Watarrka National Park.

2001 Western Plains Zoo (NSW) released some mala into larger enclosures and many of the animals died. The zoo discontinued its program housing mala for the captive breeding program.

2001 The ‘Mala paddock’ at Lake Surprise, Tanami desert NT was decommissioned, and animals were moved to the new enclosure in Watarrka NP.

2004 Monarto Zoo (SA) discontinued program to house mala for educational purposes, and these animals were translocated to Scotia Sanctuary.

2005 A new purpose built enclosure was completed at Uluru-Kata Tjuta National Park, and 24 mala were translocated there from Watarrka NP.

2010 Lorna Glen -Mala released outside of enclosure, unsuccessful reintroduction attempt, predation by wild dogs. Future releases must be to fenced enclosure with predator control.

2011 40+ individuals housed at Peron Captive Breeding Centre sourced from NT subspecies.

2011 Lorna Glen –Supplemental translocation of 34 individuals from Trimouille Island.

Genetic studies

Genetic studies of mala were conducted by Eldridge *et al.* (2004) to assist in determining the sub-specific status and relationships between the Bernier, Dorre Islands and remnant mainland populations (Eldridge and Spencer 2004). The results of the Eldridge *et al.* (2004) study have provided much needed information upon which to base future decisions about the use of source populations for reintroductions, the potential for hybridisation as also suggested by Spencer and Moro (2001) and Eldridge *et al.* 2004, exchange of animals between reintroduced populations, and the potential impact of small founder sizes of reintroduced populations.

Population viability analysis (PVA)
A PVA was undertaken by ARAZPA (Australasian Regional Association of Zoological Parks and Aquaria) in May 2004, to model the most effective methods of managing the genetics of mala stock in large predator-proof enclosures. In particular, the PVA identified gaps in data acquisition, and the need to redo the analysis with additional data.

Threat abatement

NT:
Significant improvements in the design and construction of predator-proof fences as demonstrated at Watarrka and Uluru has increased success in maintaining areas free from predator incursions.

WA:
Cat bait trials were completed successfully in Western Australia in 2008 and the Eradicat® baits are awaiting approval to be licensed which will allow continued and wider application. Access continues to be restricted to Bernier Island (day access) and prohibited on Dorre Island which reduces the threat of fire and introduction of exotic flora and fauna.

A disease hygiene protocol has been written by DEC that is applied to Bernier Island and Dorre Island (Chapman *et al.* 2008).

Community awareness, education and involvement

NT:
UKTNP rangers and Anangu (Aboriginal Traditional Owners) from the Mutitjulu Community undertake the daily educational "Mala walk" for Park visitors at the base of Uluru, which explains the cultural significance of mala to Anangu and the Park's mala reintroduction program. The Park's Cultural Centre also provides information about the species. Rangers and Mutitjulu Community members monitor and maintain UKTNP's purpose built mala paddock and plans are in place to facilitate visits to the enclosure by Anangu from other communities.

Alice Springs Desert Park zoo continues focus on mala conservation within educational programs and visitor interpretative material

WA:
Community engagement continues at Denham, the township adjacent to François Peron National Park regarding domestic cat policy, 1080 poisons and restrictions on pets in the National Park.

The World Heritage Interpretation Centre at Denham was completed in 2006 and showcases threatened Shark Bay marsupials, including mala.

The previous plan has guided the development of new actions in this revised plan. Actions that were implemented with mixed success have been reviewed. An example is the improvement of feral predator control through better exclusion fencing at the mainland sanctuaries and the development of new baits. Captive populations have been successfully maintained where feral predator incursions are controlled. Suitability of reintroduction sites have now been reconsidered with newly protected areas, such as Dirk Hartog Island National Park being identified as a candidate site once feral predators have been eradicated. New threats have been identified including drought through climate change and additional predators, other than cats and foxes, such as wild dogs. Additional actions such as monitoring have been revised e.g. island populations are now monitored annually in WA to provide better population estimates and for earlier detection of population fluctuations in response to environmental change e.g. severe drought experienced in 2008-2010. It has also been recognised that the recovery plan must be implemented by an 'active' recovery team that meets regularly and is led by a chair and coordinated by an executive officer. This is essential for the effective implementation of actions and to meet the success criteria included in this plan.

3.2 Recovery objectives and performance criteria

This Recovery Plan guides the recovery of the threatened rufous hare-wallaby including the Dorre Island subspecies and Bernier Island subspecies (Shark Bay islands subspecies) and the mala, for five years. The specific recovery objectives and recovery actions were determined through consultation with a variety of stakeholders and interest groups (see affected interests and acknowledgements).

The overall long-term objective of the recovery program is an improvement in the conservation status the mala and the Shark Bay islands subspecies of rufous hare-wallaby. However, changing of the legislative status of these taxa to anything less

threatened than ‘Vulnerable’ is unlikely within the next ten years, due to the inability to control the primary threat of introduced predators on mainland Australia in any broad-scale manner. The short-term objectives are considered to be achievable through implementation of this recovery plan over the next five years, and will contribute to the overall long-term recovery objective.

The recovery objectives of this recovery plan are to undertake conservation actions which aim to ensure the survival of all three subspecies, and if possible improve the conservation status of the mala (currently 'Endangered' under the EPBC Act) to a level that will enable down-listing to ‘Vulnerable’. Specific measurable objectives of the plan are to:

1. maintain the populations of the Shark Bay islands subspecies at their current sizes
2. maintain the mala population on Trimouille Island at its current size
3. maintain the captive mala population at its current size where appropriate
4. initiate two additional mainland or island mala populations.

Recovery plan performance criteria

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:

- within five years the estimated total number of individuals of the Bernier and Dorre Island and free-living (e.g. Trimouille Island) mainland subspecies is maintained, allowing for natural population fluctuations (to be defined as part of this process);
- within five years the number of individuals known to be alive in captivity is maintained or increased, other than through the sourcing of translocated populations;
- within five years translocations to at least two new mainland or island sites have been initiated for the mainland subspecies.

Criteria for failure:

- The estimated total number of individuals of each subspecies known to be alive on Bernier, Dorre and Trimouille Islands declines to levels below that of natural population fluctuations;
- the number of individuals of each species known to be alive in captivity declines to a level below that specified in captive management plans;
- less than two introduced predator-free mainland or island translocations are initiated within five years for the mainland subspecies.

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

3.3 Recovery actions

Action 1 Protect and monitor the Shark Bay islands populations and their habitat

This action involves:

a) Manage Bernier and Dorre Islands Nature Reserve for the conservation of the rufous hare-wallaby.

This task includes:

- ensuring compliance with existing regulations on access, fires, camping, and restrictions on non-native animals;
- detecting, monitoring, and if warranted and feasible, suppressing fires;
- implementing disease hygiene protocols for all work involving fauna trapping and handling on the islands to ensure no diseases are taken onto the islands.

Responsibility: DEC
Cost: $16,000 per year
Priority: High
Completion date: Ongoing

b) Implement an annual monitoring program.

Implement a monitoring protocol for the rufous hare-wallabies, the vegetation, and other threats on Bernier and Dorre Islands. Results of all monitoring will be reported to the Recovery Team to facilitate adaptive management of the populations and their habitat.

Responsibility: DEC
Cost: $41,000 year 1, $45,000 year 2, $49,000 year 3, $53,000 year 4, $57,000 year 5
Priority: High
Timing: Ongoing

c) Conduct additional threat abatement if required.

This task involves conducting additional threat abatement that may be required if monitoring or other evidence indicated a new threat to rufous hare-wallabies on Bernier Island or Dorre Island, This action is currently a low priority, but if a new threat is detected, immediate action may be required in order to ensure survival of the rufous hare-wallaby population.

Cost: Unknown
Priority: Low
Timing: To be implemented if necessary

Action 2 Maintain captive mala populations

The captive populations maintain representatives of the more genetically diverse mala and provide animals for future reintroduction and for public education. The need for captive populations will remain until the security of wild populations is guaranteed.

This action involves the following tasks:

a) Coordinate genetic management of all captive populations.

Captive populations will be coordinated by a single entity. This will facilitate the exchange of animals to maximise genetic diversity, streamline resource use and avoid unnecessary duplication between organisations. The Alice Springs Desert Park currently manage the stud book, and are therefore appropriate to take on this role, with guidance by staff from ZAA, the Biodiversity Conservation Unit of NRETAS and the Recovery Team. Efficiencies should be further facilitated by enhancing linkages between projects involved in the conservation of the rufous hare-wallaby.

Responsibility: Alice Springs Desert Park
Cost: $5,500 per year
Priority: High
Timing: Ongoing

b) Manage the captive populations
Managing each captive population includes:

- standard captive husbandry including maximising breeding opportunities
- controlling/reducing all relevant threats, which may include fox and cat control, fire reduction/suppression, introduced herbivore control, disease risk management and fence maintenance.

Responsibility: the manager of each facility, as indicated below.
Cost: costs provided separately below for each facility.
Priority: Varies for each facility according to the relative ability of the population to contribute to future translocations
Timing: Ongoing

Watarrka National Park.
Responsibility: Park Management and Biodiversity Conservation Units of NRETAS
Cost: $45,000 year 1, $48,000 year 2, $51,000 year 3, $54,000 year 4, $57,000 year 5
Priority: High

Alice Springs Desert Park.
Responsibility: Alice Springs Desert Park
Cost: $5,500 per year
Priority: Low

Peron Captive Breeding Centre and François Peron National Park.
Responsibility: DEC
Cost: $25,000 per year
Priority: High

Scotia Wildlife Sanctuary.
Responsibility: AWC
Cost: $5,000 per year
Priority: Medium

Uluru - Kata Tjuta National Park.
Responsibility: Parks Australia
Cost: $69,000 year 1, $48,000 year 2, then $37,000 per year
Priority: High

Action 3 Maintain and monitor the Trimouille Island mala population

- This action includes: maintaining adequate biosecurity arrangements for the island, and undertaking regular (every three years) monitoring of the population

This action also includes preparing a monitoring protocol, monitoring of the mala and monitoring the island for potential threats, such as introduced predators and competitors. Development of an island quarantine protocol (applicable to management of disease and fauna incursions all islands). The monitoring protocol will include 'early warning' thresholds of population declines that may be cause for concern, and policies for responding to any declines. Mala will be monitored using a standardised method of spotlight, and assess disease status and condition of animals of a sample of trapped animals. The population has been self-sustaining for over ten years, requiring no further translocations.

Responsibility: DEC
Cost: $25,000 year 1, $28,000 year 2, $31,000 year 3, $34,000 year 4, $37,000 year 5
Priority: Medium
Timing: Ongoing

Action 4 Reintroduction of the mala to mainland and island sites

This action includes:

a) Prepare Dirk Hartog Island for reintroduction.
Prior to the commencement of any conservation activities on Dirk Hartog Island National Park all feral cats and goats will be eradicated, following the methods successfully used by DEC on Hermite Island in the Montebello Islands (Algar *et al.* 2002) and by DEC and AWC on Faure Island (Algar *et al.* 2001).

A reintroduction of mala will then be conducted (possibly beyond the life of this Recovery Plan as the order that species will be re-introduced onto DHINP will be influenced by resources and availability of founding stock). The reintroduced population should be self-sustaining within five years, and will be monitored in accordance with the translocation documentation prepared for the re-introduction.

Responsibility: DEC
Cost: $115,000 year 1, $65,000 year 2, $50,000 pa years 3-5
Priority: Medium
Timing: Ongoing

b) Reintroduce mala to Lorna Glen enclosure and Dirk Hartog Island.
Animals are sourced from the Peron Captive Breeding Facility or Watarrka National Park.

Responsibility: DEC
Cost: $45,000 year 1, then $25,000 per year
Priority: Medium
Timing: Ongoing

c) Prepare other island/mainland sites for reintroductions, if required.

Action 5 Repeat population viability analysis (PVA)

The 2004 PVA model (section 3.1) assessed the comparative viability of wild and reintroduced populations (reintroduced populations and populations at potential reintroduction sites) to investigate ways of enhancing the long-term viability of populations under various scenarios (e.g. different reserve size, management regimes), particularly the transfer of animals between populations to increase genetic diversity. With the benefit of more recent and accurate data the PVA model should be re-run.

Responsibility: ZAA, Alice Springs Desert Park
Cost: Year 1 $6,000
Priority: Medium
Timing: Year 1

Action 6 Resolve the taxonomy genetically

Modern genetic methods should be applied to samples from existing wild and captive populations to:

- Confirm that translocated and captive populations are retaining adequate levels of founding genetic diversity;
- Confirm the relationship between the two Shark Bay island subspecies relative to each other and the mainland subspecies;
- To inform consideration of mixing island and mainland genetic stocks (e.g. for Dirk Hartog Island National Park).

Responsibility: DEC, Murdoch University
Cost: Year 1 $35,000, Year 2 $25,000
Priority: Medium
Timing: Years 1-2

Action 7 Improve community participation and education

This action includes:

a) Continue to involve the traditional owners in the management of the mala population in Uluru - Kata Tjuta National Park.
Anangu involvement has been central to all facets of the Uluru-Kata Tjunta national park mala reintroduction Project since its inception in the 1990s. This involvement is continuing in the form of ongoing enclosure maintenance, fire management, population monitoring and educating both indigenous and non-indigenous people about the species.

Responsibility: Parks Australia

Cost: $15,000 per year
Priority: High
Timing: Ongoing

b) Support involvement of the Denham community in *Project Eden.*
This action involves the following tasks:

- promoting public awareness of the fauna by providing information, interpretation and education;
- encouraging communication with the public, particularly the local community, to increase awareness of fauna conservation programs and values; and
- 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: DEC, Shire of Shark Bay
Cost: $1,500 per year
Priority: Medium
Timing: Ongoing

c) Improve community involvement in the Alice Springs Desert Park.
The current display focusing on the rufous hare-wallaby is to be maintained, and educational programs continued

Responsibility: Alice Springs Desert Park, Biodiversity Conservation Unit of NRETAS
Cost: Year 1 $15,000, then $3,000 per year
Priority: Low
Timing: Ongoing

Action 8 Coordinate the recovery program

This action includes:

a) Manage Recovery Team.
Recovery Team meetings will be held biannually, with representatives from the Biodiversity Conservation Unit of NRETAS, Alice Springs Desert Park, DEC, Parks Australia, AWC, Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), and other stakeholders as appropriate. Minutes of the meetings will continue to be circulated to participants and stakeholders within two weeks of each meeting. The Recovery Team is responsible for coordinating the recovery program, evaluating success and prioritising recovery activities.

Responsibility: NRETAS
Cost: $6,000 per year
Priority: High
Timing: Ongoing

b) Source additional funding to support recovery actions.
Many of the recovery actions described above are funded, at least in part, by in-kind contributions, such as staff salaries, infrastructure, vehicles and capital works (e.g. fencing). However, there is insufficient funding to cover all the recovery actions, thus the development of applications for funding to implement recovery actions should be encouraged and submitted to appropriate funding bodies. All members of the Recovery Team and stakeholders are responsible for pursuing funding opportunities, with the guidance of the Recovery Team.

Responsibility: Recovery Team, DEC, the Biodiversity Conservation Unit of NRETAS, Parks Australia
Cost: $3,000 per year
Priority: High
Timing: Ongoing

3.4. Implementation

The recovery program is currently supported by the input of staff and resources from the Department of Environment and Conservation (Western Australia); the Department of Natural Resources, Environment and the Arts (Northern Territory); Alice Springs Desert Park; Parks Australia; and the Australian Wildlife Conservancy.

Estimated costs of recovery actions have been calculated (Table 4), and include the salary component not met by stakeholders 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, private sponsors and large corporate sponsors.

Table 4: Implementation costs, timing and responsibility for recovery actions

Action	**3 Year cost $**	**5 Year cost $**	**Responsibility**	**Timing**
1. Protect and monitor the Shark Bay islands populations and their habitat				
a) Manage Bernier and Dorre Islands	48,000	80,000	DEC	Ongoing
b) Develop and implement a monitoring program	135,000	245,000	DEC	Ongoing
c) Conduct additional threat abatement if required	*	*	DEC	If required
2. Maintain captive mala populations				
a) Coordinate captive breeding populations	16,500	27,500	ASDP	Ongoing
b) Manage captive populations				
Watarrka National Park	144,000	255,000	NRETAS	Ongoing
Alice Springs Desert Park	16,500	27,500	ASDP	Ongoing
Peron Captive Breeding Facility	75,000	125,000	DEC	Ongoing
Scotia Wildlife Sanctuary	15,000	25,000	AWC	Ongoing
Uluṟu - Kata Tjuṯa National Park	154,000	228,000	Parks Australia	Ongoing
3. Maintain and monitor introduced Trimouille Island mala population	84,000	155,000	DEC	Ongoing
4. Reintroduce the mala to mainland and island sites				
a) Prepare Dirk Hartog Island site	230,000	330,000	DEC	Ongoing
b) Reintroduce to Lorna Glen enclosure and Dirk Hartog Island National Park	95,000	145,000	DEC	Ongoing
5. Repeat PVA	6,000	6,000	ZAA, ASDP	2015
6. Resolve the taxonomy genetically	60,000	60,000	DEC, Murdoch University	2015
7. Improve community participation and education				
a) Continue Uluṟu community involvement	45,000	75,000	Parks Australia	Ongoing
b) Enhance Denham community involvement	4,500	7,500	DEC, Shire of Shark Bay	Ongoing
c) Enhance Alice Springs community involvement	21,000	27,000	ASDP, NRETAS	Ongoing
8. Coordinate the recovery				

Action	3 Year cost $	5 Year cost $	Responsibility	Timing
program				
a) Organise Recovery Team meetings	18,000	30,000	NRETAS	Ongoing
b) Source additional funding	9,000	15,000	Recovery Team, DEC, NRETAS, Parks Australia	Ongoing
TOTAL	**1,176,500**	**1,863,500**		

* cost unknown as dependant on threat level and response required

3.5. International obligations

The rufous hare-wallaby *Lagorchestes hirsutus* is listed under the CITES — the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1975)- Appendix I (2003), as a species threatened with extinction for which international trade in specimens of these species is permitted only in exceptional circumstances.

The Shark Bay islands subspecies are found within the Shark Bay World Heritage property, inscribed in 1991 and maintained under the World Heritage Convention, and are important components of one of the four natural criteria for which the area is listed. The Uluru - Kata Tjuta National Park, where rufous hare-wallabies were reintroduced to an enclosure in 2005, is also World Heritage listed. The world heritage values of a property are "the natural heritage and cultural heritage contained in the property" (Convention Concerning the Protection of the World Cultural and Natural Heritage 1972).

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

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

The recovery plan is consistent with all of these international obligations, and implementation of the plan will help meet these obligations.

3.6. Affected interests

Organisations and people involved, or with the potential to become involved, in the conservation and management of the rufous hare-wallaby, include:

- DEC
- NRETAS

- ASDP
- DSEWPaC
- DEH
- AWC
- ZAA (formerly ARAZPA)
- CLC
- local communities
- WWF Australia
- universities

3.7 Role and interests of Aboriginal people

The Central Land Council (CLC) is a "statutory representative body" representing Indigenous Australian people in the central Australian region and plays a fundamental role in informing traditional owners of the status of threatened species in central Australia, such as the mala, and the threatening processes that have caused mammal extinctions in the area.

The mala was an important food source for Indigenous people throughout its geographic range and remains of great cultural significance to the people of the central desert region (Williams *et al.* 2001). There are Aboriginal people, residing in communities of the Northern Territory and the Shark Bay region of Western Australia, that have interest and undertake roles in the recovery of the mala.

In the Northern Territory, the Commonwealth Department SEWPaC, Parks Australia Division, manages Uluṟu-Kata Tjuṯa National Park, with the traditional owners, the Aṉangu, and the local Mutitjulu community. The Aboriginal traditional owners lease the National Park to Parks Australia under joint management.

A cross-cultural workshop entitled *Biodiversity and the Re-introduction of Native Fauna at Uluṟu - Kata Tjuṯa National Park* (Gillen 1999) was held at Yulara in September 1999 to identify and discuss the issues surrounding the re-establishment of locally extinct fauna within the Uluṟu - Kata Tjuṯa National Park. The mala was identified as a priority species for reintroduction. As a result of this, Parks Australia and the traditional owners began construction of a 170-hectare enclosure at Uluṟu in 2004. It was completed in September 2005 and 24 mala were translocated from Watarrka in September 2005. Active involvement in the project by Indigenous Australians will continue as both the mala 'Tjukurpa' (Anangu Traditional Law), and the species itself, are of great significance to Anangu.

The Walpiri people assisted with the construction of the 'Mala Paddock' near Lake Surprise in the Tanami Desert in the Northern Territory (Burbidge *et al.* 1999), and the ongoing maintenance of the mala colony until decommissioning in 2003. The Walpiri people participated in the translocation of the species from the 'Mala Paddock' to Trimouille Island in 1998 (Burbidge *et al.* 1999; Langford and Burbidge 2001) and to the Peron Captive Breeding Centre in Shark Bay in 1999.

In Western Australia, the Aboriginal Sites Register is maintained by the Department of Indigenous Affairs and lists significant sites on Bernier and Dorre Islands in Shark Bay, and also in the vicinity of potential translocation sites at Dirk Hartog Island and Peron Peninsula. Not all significant sites are listed on the Register. Officers involved in translocations and activities near to known significant sites will be briefed to ensure that sites are not disturbed during these activities.

The Yadgalah Aboriginal Corporation from Denham, Shark Bay, has been consulted and maintains an interest in the actions associated with the recovery of the species outlined in this Recovery Plan.

The DEC Indigenous trainee program (MATES) has employed a number of Indigenous personnel at Shark Bay, whose work programs have included involvement in a number of *Project Eden* activities.

Implementation of recovery actions under this plan will continue to include consideration of the role and interests of Indigenous communities in the region, and this is discussed in the recovery actions. Input and involvement into preparation of the recovery plan has been sought from Aboriginal groups that have an active interest in areas that are or were habitat for the rufous hare-wallaby.

3.8 Benefits to, and negative impacts on other species

Actions associated with the recovery of the rufous hare-wallaby may benefit a wide range of other native fauna and flora species. The control of introduced predators at reintroduction sites will benefit many critical weight range mammal species (small to medium sized mammals weighing between 35 and 5,500 grams, many of which have declined or become extinct in the last 200 years since European settlement of Australia; Burbidge and McKenzie 1989), and may facilitate reintroductions of other species of threatened fauna. For example, malleefowl *Leipoa ocellata* and greater bilbies *Macrotis lagotis* have been successfully reintroduced in the François Peron National Park (Morris *et al.* 2004, Mawson 2004). Predator control in the area has been associated with an increased abundance of a number of reptile species (e.g. Gould's monitor *Varanus gouldii*, bobtail skink *Tiliqua rugosa*, thorny devil *Moloch horridus*), the echidna *Tachyglossus aculeatus*, and several other threatened species that occur in the region (e.g. thick-billed grasswren *Amytornis textilis textilis*, southern woma python *Aspidites ramsayi*; C. Sims[10], personal communication).

Within extensive enclosures that house rufous hare-wallabies, such as at Watarrka National Park and Peron Captive Breeding Facility, native flora and fauna may benefit from the presence of native species and absence of introduced species (foxes, cats, rabbits).

Research into reintroduction techniques may assist in the conservation of other threatened mammals in Australia and elsewhere. Conservation agreements with landholders or changes in land tenure may benefit the long-term security of reintroduction sites throughout Australia for the conservation of threatened mammals and their habitat.

There are no likely negative impacts of recovery actions on native species or ecological communities. Monitoring to determine the uptake and impact of novel baits by non-target species is required prior to any wide-scale use of baits for management of feral cats. Research into non-target bait uptake has been carried out at a range of sites throughout Australia. Its use would negate issues surrounding non-target uptake of baits. Broad-scale baiting for foxes and dingos in Australia, particularly in the arid zone, has led to changes in the abundance of feral cats and rabbits (e.g. Christensen and Burrows 1994; Risbey *et al.* 1999, Short and Turner 2000, Robley *et al.* 2002), which in turn has altered interactions between introduced species and native fauna. Land managers must take into consideration the interactions between native and introduced fauna and their habitats, many of which are unknown, when implementing predator control, to avoid negative impacts on non-target native species.

3.9 Social and economic impacts and benefits

The implementation of this recovery plan is unlikely to cause adverse social and economic impacts, and is more likely to assist in encouraging positive benefits through tourism in the Shark Bay and Uluru regions, reinvigoration of Tjukurpa for traditional owners in the Uluru region, and transmission of traditional knowledge through the generations.

[10] Colleen Sims, Project Eden Coordinator, Shark Bay District, DEC, Denham.

Tourism

Tourism is an important industry associated with the areas in which captive colonies of the rufous hare-wallaby are or may be maintained.

In the Northern Territory these areas include Watarrka National Park, Alice Springs Desert Park, and Uluru - Kata Tjuta National Park. Over two million domestic and international tourists visit the Northern Territory annually, with over 250,000 people visiting Watarrka National Park alone (PWCNT 2003), bringing economic benefits to the community. This level of visitation does place localised pressure upon the environment, including sites of significance to Indigenous Australians (Rose 1995).

Watarrka National Park acts as a hub of threatened species conservation projects. With over 250,000 visitors a year, the area provides ample opportunity for conservation awareness programs, visitor interpretive facilities, economic opportunity, and sponsorship attractiveness. It is also envisioned that limited and appropriately managed access to the mala enclosure will be provided for members of the public interested in assisting with on-ground recovery actions. Uluru - Kata Tjuta National Park has not indicated any plans for tourism involvement in the captive colony maintained there

In Western Australia, tourism areas include François Peron National Park and Shark Bay where tourism is considered the major industry (Reark Research *et al.* 1995).

François Peron National Park is accessible to tourists and has seen a dramatic increase in the number of visitors since the inception of *Project Eden* in the early 1990s (DEC Denham visitor statistics). A continuing aim is 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 on Shark Bay.

The Shark Bay region is focussed strongly on the region's unique natural environment. The Shark Bay visitor centre conducts guided night walks to view a range of threatened native mammal species.

Actions associated with the recovery of the mala are unlikely to impact negatively on tourism activities, and further development of sensitive ecotourism activities, would continue to benefit the region.

Pastoral

Dirk Hartog Island was vested with DEC as a National Park in 2010 following a long term pastoral lease on the island. The previous pastoral activities that were incompatible with conservation of this species will no longer pose a threat. The National Park will now be managed with the objective of conservation of rufous-hare wallabies with the aim to reintroduce the species to the island once feral animals have been eradicated.

Local communities

Economic benefits through the construction of the the predator-proof fence for the Mala enclosure at Uluru - Kata Tjuta National Park were positive, with the project

providing work to 35 Anangu community members. Other opportunities for employment associated with recovery actions would be well received..

Both the development of skills and an income have provided positive social and economic benefits for the Mutitjulu community. Other positive benefits have been the reinvigoration of 'Tjukurpa' for traditional owners at Uluru, and transmission of traditional knowledge through the generations.

It is likely that many of the recovery actions for the mala outlined in the plan may increase local community knowledge, pride and involvement in the conservation of the species and its habitat, along with other native fauna within reintroduction sites at Watarrka, Uluru - Kata Tjuta and François Peron National Parks. Actions outlined are unlikely to impact negatively on the resident human communities within these regions.

3.10 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 matters of national environmental significance (including listed threatened species and world heritage properties) should refer the action to the Minister for Sustainability, Environment, Water, Population and Communities. The Minister will determine whether the action requires EPBC Act assessment and approval. Further advice on the EPBC Act is available on the Department of Sustainability, Environment, Water, Population and Communities website (DSEWPaC 2010).

Possible future actions that may constitute a significant adverse impact on the mala include those that may:

- increase the risk of introduction of feral predators onto islands inhabited by the species;
- increase the risk of incursions of feral predators to translocation sites;
- hamper the control of feral predators in habitat critical to survival of the species;
- increase the likelihood of wildfire in habitat critical to survival of the species;
- increase the risk of the introduction of diseases to wild or translocation sites; and
- increase human use of islands inhabited by the species for recreation or other purposes that may increase the likelihood of introduction of exotic species or fire.

3.11 Management Practices

Management practices (policies, strategies, plans) that have a role in the protection of the species include but are not limited to the following.

- Faure Island Pastoral Lease Management Plan (Australian Wildlife Conservancy 2002)
- Heirisson Prong Community Biosphere Reserve Management Plan 1999 – 2004 (Short 1999)
- 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)
- Minimising Disease Risk in Wildlife Management. 2nd Edition (Chapman *et al*. 2008)
- Policy Statement No. 29 *Translocation of Threatened Flora and Fauna* (CALM 1995).

To minimise the risk of wildfire to mala, management practices such as prescribed burning, firebreaks, and back-burning, are required. DEC address this in WA through the Incident Management System and the 'Master Burn Plan' and set annual priorities for areas to be burnt prescriptively to reduce fuel loading in an effort to reduce the intensity and frequency of wildfires. Areas where threatened species persist or have been introduced are considered high priority assets and efforts are made to exclude fire where practicable from these areas.

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APPENDIX 1 - Mala Recovery Team

Organisation
Biodiversity Conservation, Department of Natural Resources, Environment, Arts and Sport, NT
Shark Bay District, DEC
Science Division, DEC
Biodiversity Conservation Group, Science Division, DEC
Species and Communities Branch, DEC
Alice Springs Desert Park
Zoo and Aquarium Association
Australian Wildlife Conservancy
Central Land Council
Uluṟu - Kata Tjuṯa National Park
Desert Graphics
Wildlife Research and Management
Murdoch University, School of Biological Sciences and Biotechnology
National Parks and Wildlife Service, NSW

APPENDIX 2 - Detailed information on previous and existing Recovery Actions

Recovery Team and planning

A Recovery Team (Appendix 1) for the rufous hare-wallaby was established in 1993 by the Parks and Wildlife Commission of the Northern Territory (PWCNT; now the Biodiversity Conservation Unit of NRETAS), to coordinate conservation actions for the species. The Recovery Team has guided past and current recovery actions. Annual meetings to review the progress of the Recovery Plan and modify recovery actions where necessary, are organised by NRETAS, with participation from DEC, Alice Springs Desert Park, DSEWPaC, Parks Australia, AWC and other organisations and community groups as appropriate.

The previous *Recovery Plan for the Mala 2000 – 2004* (Langford 2001) was adopted by Environment Australia (now the Department of Sustainability, Environment, Water, Population and Communities) in 2001. Maintenance of the existing wild populations on Bernier and Dorre Islands are key objectives and actions outlined in the *Shark Bay Terrestrial Reserves Management Plan* (Hancock *et al.* 2000), the *1996 Action Plan for Australian Monotremes and Marsupials* (Maxwell *et al.* 1996), the previous *Mala Recovery Plan* (Langford 2001) and the *Report on Threatened Shark Bay Marsupials* (Richards 2003).

Assistance with the maintenance of the mala recovery team is the responsibility of DEC.

Monitoring of wild populations

The only systematic monitoring of the Shark Bay islands subspecies was carried out by CSIRO, who conducted comprehensive spotlighting and trapping surveys of Bernier and Dorre Islands in 1988 and 1989 and repeated these three years later (Short and Turner 1992; Short *et al.* 1997b). Other monitoring has typically been sporadic and ad hoc, conducted opportunistically by hand netting (detailed by Richards *et al.* 2001). There has been no long term, consistent and cohesive approach to monitoring.

Maxwell *et al.* (1996) and Langford (2001) recommended that monitoring of the Shark Bay islands subspecies be carried out every three years. DEC held a workshop on monitoring regimes for the threatened mammals on Bernier and Dorre Island in 2003, with participants from DEC, CSIRO and AWC. The consensus was that regular monitoring was important.

Introduction and reintroduction

A number of unsuccessful reintroductions of the mala were carried out in the Northern Territory in the Tanami Desert between 1984 and 1992 by PWCNT (Table 1). One reintroduction was located at the site of the wild colony that became extinct in 1987 at Sangster's Bore (Gibson *et al.* 1994b). A second was undertaken in the fresh-water palaeodrainage line that traditional Aboriginal owners selected on the basis of "habitat suitability and use by mala in living memory" at the site of the 'Mala Paddock', 15 km south east of Lake Surprise and 500 km north northwest of Alice Springs (Lundie-

Jenkins and Bellchambers 1994; Lundie-Jenkins and Moore 1996, p. 9). Both reintroductions failed due to predation by feral cats (Short *et al.* 1992; Gibson *et al.* 1994b), despite populations persisting at both sites for between 20-38 months (Lundie-Jenkins and Moore 1996).

In Western Ausrtalia, successful fox baiting of the 105,000-hectare Francois Peron Peninsula was implemented in 1995 and feral cat control began in 1996 under *Project Eden*. Despite a decrease in cat numbers, a reintroduction of the mala and banded hare-wallaby *Lagostrophus fasciatus fasciatus* in 2001 failed due to predation by feral cats. This prompted a reconsideration of plans to reintroduce a suite of threatened mammals at the site (Mawson 2004; Morris *et al.* 2004; Hardman 2006).

Mala from the 'Mala Paddock' in the Tanami Desert in NT were introduced successfully to the 520 ha Trimouille Island in the Montebello Islands Conservation Park off the Pilbara coast of Western Australia in 1998. This followed a program of feral cat and rat eradication through DEC's *Montebello Renewal Project* (Burbidge *et al.* 1999; Langford and Burbidge 2001). This introduction was considered a success, indicating that the use of predator-free islands for additional introductions is a more practical approach than unfenced mainland sites.

A range of sites have been identified as potential reintroduction sites (Maxwell *et al.* 1996), such as Lorna Glen, Dirk Hartog Island National Park and Mount Gibson Sanctuary where feral cats may be controlled to low levels.

Captive breeding

The mala stud book is managed by the curator of Zoology at the Australasian Zoo and Aquarium Association (ZAA) (formerly ARAZPA) accredited zoo Alice Springs Desert Park using the Single Populations Analysis and Record Keeping System (SPARKS). The SPARKS program (Wilcken and Lees 1998; ISIS 2002) and PM2000 (Pollak *et al.* 2002) are used to maintain the studbook and make pairing decisions for active captive breeding programs.

Captive breeding colonies have been established at a range of sites, outlined in Table 2. Intensive pen systems have been successfully used for breeding the mala (e.g. Peron Captive Breeding Centre) and are typically associated with a much higher cost of production than more extensive pen systems (Mawson 2004).

In the Northern Territory, the Parks and Wildlife Commission of the Arid Zone Research Institute (AZRI) in Alice Springs maintained a captive population of the mala from 1980. However this was decommissioned in 2001 and animals were transferred to the Alice Springs Desert Park where a colony of 8 mala is still housed primarily for educational purposes. Animals are displayed in a nocturnal house for viewing by the general public, and are used as a "flagship" species for the conservation of threatened species (Langford 2001).

Mala were originally also housed in an enclosure near Lake Surprise (Yinapaka) in the Tanami Desert 500 km NW of Alice Springs from 1986 (sourced from 22 founders from the remnant wild Tanami Desert population (Langford and Burbidge 2001)). This enclosure was located on the floodplain of the Lander River, near the Indigenous Australian community of Willowra. The enclosure was decommissioned

in 2001 and a replacement 120-hectare predator-proof enclosure was purpose-built in 2000 within the Watarrka National Park. The purpose of the enclosure at Watarrka National Park is to maintain at least 150 animals to secure representatives of the mainland gene pool and provide animals for translocation to other captive breeding facilities and reintroduction sites free of introduced predators. The captive population will continue to be monitored at least twice a year.

Late in 2002, the *Uluru - Kata Tjuta National Park Species Reintroduction Project* was established to construct a feral-proof enclosure at Uluru, based upon the design of the enclosure at Watarrka National Park, with advice from the Arid Recovery Project and Australian Wildlife Conservancy regarding fence design, and to reintroduce the mala (Liddle 2004).

The purpose-built, 170-hectare enclosure surrounded by a four-metre firebreak was completed in September 2005, with the involvement of Anangu, the Mutijulu community, Green Corps, and staff from Parks Australia. The external perimeter is burnt to a buffer of up to 100 m from the fence line to minimise fire risk. All introduced predators have been eradicated and the enclosure is to be maintained free of camels, rabbits, foxes, cats and dingos. Twenty four mala were translocated to the enclosure from Watarrka National Park in September 2005. The colony will continue to be monitored at least twice a year, and genetic diversity managed through the studbook.

The project is unique, in that it serves the dual purposes of the conservation of both natural and cultural heritage, as it is in close proximity to the cultural centre and is managed by Parks Australia.

Scotia Wildlife Sanctuary in the Murray-Darling Basin area of New South Wales has been owned by AWC since 2002 and was formerly owned by Earth Sanctuaries Ltd., who purchased Ennisvale and Tarrara Pastoral Stations in the mid-1990s to form Scotia (Fleming 2005). Predator-proof fencing protects an area of 8,000 ha within the 64,000 ha sanctuary, and a captive breeding colony of > 20 mala is currently maintained within a 100-hectare enclosure as a source of animals for future translocations.

The Western Plains Zoo in New South Wales and the Monarto Zoological Park in South Australia, both members of ZAA, housed mala to support the captive breeding program and for educational purposes until 2001 and 2004, respectively. Both programs were discontinued. Western Plains Zoo released mala into larger enclosures in 2000/1 and many of the animals died, possibly due to wet conditions, so the release program was discontinued. The Western Plains Zoo retained a single aging mala for display purposes only but this has since died.

In Western Australia, at Shark Bay, DEC is responsible for the management of Bernier and Dorre Islands, and the François Peron National Park, and their resident wild, captive and reintroduced populations of marsupials, including the mala.

The DEC managed program, *Project Eden*, aimed to reconstruct and rejuvenate an entire ecosystem in the François Peron National Park on the 105,000 hectare Peron Peninsula, by controlling introduced predators and reintroducing a suite of native fauna (Morris *et al.* 2004).

A captive breeding colony of over 40 mala is currently housed in small enclosures at the Peron Captive Breeding Centre (PCBC) and within three 16 ha enclosures with dense, low vegetation within the François Peron National Park. This facility will continue to provide security for representatives of the mainland gene pool, and will be managed through the studbook to supply animals for exchange to other captive breeding programs and reintroductions. Some of these animals are intended for release to Dirk Hartog Island.

Genetic studies

Genetic studies of mala were conducted by Eldridge *et al.* (2004) to assist in determining the sub-specific status and relationships between the Bernier, Dorre Islands and remnant mainland populations (Eldridge and Spencer 2004). The results of this study have provided much needed information upon which to base future decisions about the use of source populations for reintroductions, the potential for hybridisation (as suggested by Spencer and Moro 2001 and Eldridge *et al.* 2004) and exchange of animals between reintroduced populations, and the potential impact of small founder sizes of reintroduced populations. The mainland population has retained substantial genetic diversity, whereas the Shark Bay islands populations possess levels of genetic diversity that were amongst the lowest reported for other marsupials, and elevated inbreeding, that is thought to be associated with reduced population persistence and evolutionary fitness (Eldridge *et al.* 2004). Eldridge *et al.* (2004, p. 332) regarded the Shark Bay islands subspecies as "relatively unsuitable for reintroduction to the mainland except as a last resort", though local adaptations may mean that the subspecies are better suited to the Shark Bay region than the mala.

Feral predator control

A number of studies on the control of feral cats have been undertaken by DEC, CSIRO and the Arid Recovery Project, including trials of methods of trapping, the use of a variety of baits and lures, and poisoning (Algar and Sinagra 1996; Risbey *et al.* 1997; Short *et al.* 1997a; Short *et al.* 2002; Arid Recovery Project 2002; Algar *et al.* 2002; Algar and Burrows 2004). CSIRO has had success in controlling cats using mouse carcasses impregnated with 1080 poisoned 'one-shot oats', applied in late autumn when prey abundance (rabbits) was low (Short *et al.* 1997a). The Invasive Animals Cooperative Research Centre (IACRC), in collaboration with DEC and AWC, have completed a seven-year research program to develop techniques for integrated pest management, with particular emphasis in Western Australia on the dynamics of feral cats and methods for their broadscale control. DEC has specifically developed a kangaroo meat sausage bait for feral cats, impregnated with 1080 that has shown considerable signs of success in controlling cat numbers (Algar and Burrows 2004). Field trials of the Eradicat® bait were successful, and the baits are under consideration with the AVPMA (Australian Pesticides and Veterinary Medicines Association) with the expectation that the baits will be licensed for more widespread use within the near future (D. Algar[11] personal communication).

Successful cat control has been achieved on islands (Burbidge and Manly 2002). However, the successful broadscale application of cat control methods on the mainland in the arid and semi-arid zone has so far met with varied success. For

[11] David Algar, Research Scientist, DEC, Perth.

example, an aerial baiting trial of DEC's kangaroo sausage baits was carried out in 2002 in a buffer zone surrounding the Arid Recovery Reserve near Roxby Downs in South Australia. 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, Algar and Burrows (2004) and Morris *et al.* (2004) reported an 80% reduction in cat numbers in the 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 hare-wallabies. Recent trials in the Gibson Desert and at Lorna Glen in Western Australia by DEC have met with some success, with 80-100% of radio collared cats eradicated after successive years of baiting (Algar and Burrows 2004; D. Algar[11] personal communication).

In contrast, malleefowl and bilbies have been successfully established at François Peron National Park, 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, including the rufous hare-wallaby, is 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 mala.

Population viability analysis (PVA)

PVA provides a technique for predicting the possibility of extinction or persistence of a population within a time frame into the future using modelling (Possingham and Davies 1995). Processes within small populations are unpredictable; therefore only the potential fate of populations can be modelled, based on simulated probabilities (Lacy 1993). By adjusting parameters within the model (such as founder population size, reserve size, frequency of predation event) it may be used as a management tool, assisting to determine suitability of potential reintroduction sites for mala, through determining the potential persistence of both wild and reintroduced populations.

A PVA was undertaken by ZAA in May 2004, to model the most effective methods of managing the genetics of mala stock in large predator-proof enclosures. In particular, the PVA identified gaps in data acquisition, and the need to redo the analysis with additional data. The results suggested that the Watarrka National Park population was robust, which was supported soon after by the recovery of the population after a major fire event.

Community awareness, education and involvement

In the Northern Territory, the local Anangu and Mutijulu Community have been heavily involved in the creation of the Uluru Cultural Centre and the 'Mala Walk' around the base of Uluru to enhance awareness by the general public, and more recently, in the establishment of the purpose-built paddock near the Cultural Centre to house the mala. This involvement will continue.

The Alice Springs Desert Park has a display of mala and includes aspects of the mala conservation in educational programs. The display provides information about the plight of threatened species in Australia, and the recovery actions being undertaken to address the threats to these species.

In Western Australia, the Denham community adjacent to François Peron National Park currently has restrictions on the presence of unsterilised domestic cats and DEC has campaigned residents about the presence and use of 1080 poison in the region. It is important to maintain awareness activities for new residents as there is often tension associated with domestic cat control policies and the distribution of 1080 poison. The use of 1080 has been blamed for the death of domestic dogs at Denham, in addition to existing restrictions in taking pets into National Parks, reducing the accessibility of locations for recreational pursuits with pets. Any tension should be consistently assuaged, as any changes to current practice would require investment in further community consultation.

The *Project Eden* Community Advisory Committee was established with the inception of *Project Eden,* however the group has been inactive since 2005. *Project Eden* has a high profile within the community and hosts school, university and teacher education programs, Australian and international volunteers, and work experience students.

Specific recommendations of The *Shark Bay Terrestrial Reserves Management Plan* (Hancock *et al.* 2000) include promoting public awareness of the threatened Shark Bay 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 environmental values.

The World Heritage Interpretation Centre at Denham was completed in 2006 and showcases threatened Shark Bay marsupials, including mala. This display assists in providing local, national, and international education about the plight of the mala and the recovery actions that are being undertaken to ameliorate threats to the species. The display enables visitors to learn more about the area and to appreciate its distinctive values.

Island management

Bernier Island is maintained as a day-use area only, with no overnight camping permitted and Dorre Island is a prohibited access area (Hancock *et al.* 2000). Other than routine management of Bernier and Dorre Island Nature Reserves, and the disease protocols described above (Chapman *et al.* 2008), no actions have been undertaken specifically to assist in the conservation of the Shark Bay islands subspecies.