Numbat

(*Myrmecobius fasciatus*)

Recovery Plan

Wildlife Management Program No. 60

Western Australia Department of Parks and Wildlife

September 2015

Department of Parks and Wildlife

Australian Government

Wildlife Management Program No. 60

Numbat
(*Myrmecobius fasciatus*)
Recovery Plan

September 2015

Western Australia Department of Parks and Wildlife
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983

Foreword

Recovery plans are developed within the framework laid down in the Western Australian Department of Parks and Wildlife Policy Statements Nos. 44 and 50 (CALM 1991, 1995), and the Australian Government Department of the Environment's Recovery Planning Compliance Checklist for Legislative and Process Requirements (Department of the Environment 2014).

Recovery plans outline the recovery actions that are needed to urgently address those threatening processes most affecting the ongoing survival of threatened taxa or ecological communities, and begin the recovery process. Recovery plans are a partnership between the Department of the Environment and the Department of Parks and Wildlife. The Department of Parks and Wildlife acknowledges the role of the *Environment Protection and Biodiversity Conservation Act 1999* and the Department of the Environment in guiding the implementation of this recovery plan. 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.

This recovery plan was approved by the Department of Parks and Wildlife, 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. Information in this recovery plan was accurate as of September 2015.

Acknowledgments: This recovery plan was prepared by Tony Friend and Manda Page (Department of Parks and Wildlife) for the Numbat Recovery Team. Valuable contributions were received from the members of the recovery team and other Parks and Wildlife staff. Sandra Gilfillan worked on an early draft.

Citation: Department of Parks and Wildlife (2015). Numbat (*Myrmecobius fasciatus*) Recovery Plan. Wildlife Management Program No. 60. Prepared by J.A. Friend and M.J. Page, Department of Parks and Wildlife, Perth, WA.

Cover photograph: Numbat (*Myrmecobius fasciatus*). Photograph: Tony Friend (Department of Parks and Wildlife).

Abbreviations

AWC	Australian Wildlife Conservancy
CALM	Department of Conservation and Land Management, Western Australia (changed to Department of Environment and Conservation in July 2006)
DEC	Department of Environment and Conservation, Western Australia (formerly CALM; changed to Department of Parks and Wildlife July 2013)
DoP	Department of Planning, Western Australia
DoTE	Commonwealth Department of the Environment, formerly Department of Sustainability, Environment, Water, Population and Communities
DPaW	Department of Parks and Wildlife, Western Australia (formerly DEC)
EPA	Environmental Protection Authority, Western Australia
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
FPC	Forest Products Commission, Western Australia
IBRA	Interim Biogeographical Regionalisation for Australia
IUCN	International Union for Conservation of Nature
NP	National Park
NR	Nature Reserve
SF	State forest
WA	Western Australia
WAPC	Western Australian Planning Commission
WWF	World Wildlife Fund for Nature

Contents

Summary

Species: *Myrmecobius fasciatus*
Family: Myrmecobiidae
Common Name: Numbat
IBRA Regions: Avon Wheatbelt, Jarrah Forest, Mallee, Swan Coastal Plain, Warren
Parks and Wildlife Regions: South Coast, South West, Swan, Warren, Wheatbelt
National Locations: Yookamurra Sanctuary (SA); Scotia Sanctuary (NSW)

Current conservation status:

- Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act): Vulnerable.
- Western Australian *Wildlife Conservation Act 1950* (WC Act): Schedule 1, rare or likely to become extinct. Ranked as Vulnerable (using IUCN criteria).

Habitat critical to survival:

The numbat's historic distribution encompassed a number of habitat types, including eucalypt forest, eucalypt woodland, *Acacia* woodland and *Triodia* grassland. Known numbat subpopulations occupy several different habitat types, but only a small proportion of the range of habitat types previously occupied by the species.

The key habitat requirements of the numbat, based on habitats occupied throughout its past range and those where the species currently occurs include:

- Presence of termites in sufficient abundance - all evidence relating to the diet of the numbat throughout its range indicates an almost complete dependence on termites (Calaby 1960).
- Sufficient cover - adequate cover near ground level is required to provide refuge from raptors. Cover may be provided by thickets or a combination of thickets and hollow logs. An exception to this may be the apparent existence of numbat subpopulations in *Triodia* tussock grasslands of the arid zone, but these may have relied on proximity to woodland patches.
- Sufficient openness - although a degree of cover is required for refuge from predators, a sufficiently open understorey is required for feeding sites. A combination of an open understorey interspersed with thickets and hollow logs is ideal.
- Presence of eucalypt species - the majority of sites where numbats occur and were recorded in the past are characterised by the presence of eucalypt species thus providing logs and hollows and possibly higher termite densities.

Incorporation of management practices such as the retention of logs and hollows during timber harvesting and burning operations and implementation of introduced predator baiting programs are important to the conservation of the numbat. Numbats need large areas of natural woodland vegetation because of their relatively large home ranges and limited food resources. Corridors of native vegetation with adequate low vegetation cover are important to maintain in agricultural areas as they will be used by dispersing young.

All subpopulations are considered necessary for long-term survival of the species. Importance is attributed to the original subpopulations and to ones sufficiently large to be considered self-sustaining or that have the potential to become self-sustaining.

Current threats

- Predation by feral cats and foxes
- Inappropriate fire regimes
- Habitat fragmentation and disturbance
- Disease
- Climate change

Recovery goals and objectives

The long term goal of the recovery program for the numbat is to improve its conservation status by increasing the size of existing subpopulations and increasing the number of subpopulations.

This recovery plan guides the recovery of the numbat for the next 10 years. The objectives are to:

1. Ensure the security of existing self-sustaining[1] subpopulations.
2. Extend the current distribution of the numbat.
3. Ensure genetic health and diversity is maintained.
4. Increase community awareness and participation in the conservation of the numbat.

Criteria for success:

This recovery plan will be deemed successful if, within a 10 year period, all of the following are achieved:

- All subpopulations currently assessed as self-sustaining persist.
- Additional subpopulations have been established at one or more sites.
- Genetic health and diversity is described and maintained.
- Increased recognition of the status of the numbat and support towards its conservation.

Criteria for failure:

This recovery plan will be deemed unsuccessful if, within a 10 year period, any of the following occur:

- Any of the subpopulations currently assessed as self-sustaining are lost.
- No additional subpopulations have been established.
- No increased recognition of the status of the numbat or support towards its conservation.

[1] For the purpose of this recovery plan, a self-sustaining population is defined as a population that has persisted for at least five years after the most recent release (excluding releases for the purpose of genetic exchange) under the current management regime, without the need for additional inputs or management. Note such a population may still be declining.

1. Introduction

This document constitutes a formal recovery plan for the numbat (*Myrmecobius fasciatus*) and provides information on distribution, decline, aspects of ecology and biology, and threatening processes, and presents the actions and associated costs, considered necessary to recover this species.

1.1 Description

Numbats are small marsupials of distinctive appearance. Adults have a head and body length of 200-250 mm and tail length of 150-180 mm. Males attain slightly higher body weights than females (maximum 700 g and 550 g respectively).

The numbat's overall colour is reddish brown which is the predominant colour of the head and upper back. There is a distinct horizontal black stripe through the eye and partway down the back. The faint white bands across the body become stronger towards the rump and are accentuated by the progressively darker and eventually jet-black bands between the white bands. The number of white bands varies between four and eleven. The bands are often broken with the two halves offset along the midline. The pattern formed by these bands is unique to the particular animal, and may be used to identify individuals. The hair on the underside of the body is off-white. The tail is covered with long brown hairs, many of which are tipped with white. The underside of the tail, near the body, is brick-red.

The numbat has a pointed nose and elongated jaw which houses 50-52 teeth, the largest number recorded in any Australian terrestrial mammal. The teeth are poorly developed and many do not protrude beyond the gums. The tongue is exceptionally long and can be extended at least 5 cm beyond the tip of the nose (about the length of the head).

1.2 Conservation status

The numbat has been listed as specially protected fauna that is rare or likely to become extinct under the WA *Wildlife Conservation Act 1950* since 1973, and is ranked as Vulnerable in WA under Department of Parks and Wildlife policy using IUCN criteria. It is listed nationally as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and as threatened (Endangered category) in the IUCN Red List (IUCN 2013).

Early in the life of the previous recovery plan (Friend 1994), the species was down-listed from Endangered to Vulnerable on the national and IUCN lists. In 2008 the numbat's status on the IUCN Red List was changed back to Endangered based on the findings of the Global Mammal Assessment process (Friend and Burbidge 2008). A review of the numbat's conservation status in 2010 (DEC 2010a)

drew attention to recent declines in key subpopulations, despite some successful translocations and increases in original subpopulations, and the Action Plan for Australian Mammals 2012 (Woinarski *et al.* 2014) recommends the conservation status of Endangered.

1.3 History and taxonomic relationships

The first specimen of the numbat to attract scientific attention was captured a short distance north-east of present-day Brookton WA, by Ensign Richard Dale and George Fletcher Moore during an exploration trip in 1831 (Dale 1833, Moore 1884, Friend 1989). This specimen was described as a new genus and species in a brief note by Waterhouse (1836). He considered that the numbat was closest to the family Dasyuridae (the carnivorous marsupials) but was unsure of the affinities of the species.

Gill (1872) placed the numbat in its own family (Myrmecobiidae) in the Order Dasyuromorphia. Cranial and dental morphology, as well as findings from serology and allozyme electrophoresis support the theory that the numbat is descended from dasyurid stock, and that many of the anatomical differences that exist now between it and the dasyurids are the result of adaptation to a specialised diet of termites (Calaby 1960, Griffiths 1968, Friend 1989). A recent investigation of the morphology of numbat sperm shows significant differences from the dasyurid pattern, justifying the retention of the Myrmecobiidae family (D. Taggart, pers. comm.). Beyond the placement of the family in the Dasyuromorphia, the numbat's relationships remain uncertain (Wroe and Musser 2001; Krajewski and Westerman 2003). A recent comparison of all extant dasyurid genera and the numbat with the genome of the Tasmanian Devil, however, confirmed the numbat's position in the Dasyuromorphia and placed it as the sister group to all living Dasyuridae (Zemann *et al.* 2013).

Most of the museum specimens collected subsequently have come from south-western Australia, but a significant number were collected in arid and semi-arid areas of Western Australia, South Australia and New South Wales. Several differences between the arid specimens and those from the south-west of Western Australia prompted Finlayson (1933) to separate the desert form, largely based on its redder coloration. This redness is likely a selective adaptation, which provides greater protection against avian predation where the soil is redder in colour. It appears that this form no longer exists (Friend *et al.* 1982).

1.4 Distribution

Historical

Historical reconstruction of the numbat's range before European settlement in the early 1800s has been based on museum specimens collected alive, remains found in subfossil deposits, published anecdotal accounts and Aboriginal knowledge recorded through interviews (Friend 1990). Records of the species are scattered across a wide arc stretching from western New South Wales and south-eastern South Australia, north to the southern border of the Northern Territory and across to the south-west of Western Australia (Figure 1). There are no records of the numbat from Victoria but it is likely it occurred in the north-west corner of that State.

The contraction of the numbat's range, traced from the latest records in any particular region, followed an east-to-west progression (Friend 1990; Friend and Thomas 2003), commencing with the apparent decline of the species near the Murray-Darling confluence in the 1850s (Krefft 1866). Numbats were present near Adelaide at the time of European settlement, but disappeared soon after (Wood Jones 1923). The contraction was slow until the 1920s, when the range of the introduced fox (*Vulpes vulpes*) expanded rapidly westward, following in the wake of colonisation by rabbits (*Oryctolagus cuniculus*) from south-eastern Australia (Friend 1990). In Western Australia, there are no records of numbats from the Goldfields region after 1930, although they may have persisted there unrecorded somewhat longer (Friend 1990).

Several observers in the 1940s predicted the numbat's demise, even in its south-western stronghold (Anon 1949), but some optimism returned in the 1950s with an increase in sighting rates at several key sites in WA (Jones 1954; Serventy 1954). By the mid-1960s, numbats persisted only in the southwest and in the Gibson Desert and surrounding areas (Friend 1990). By 1982 no desert populations remained (Friend *et al*. 1982). This extinction was part of the dramatic collapse of the mammal fauna of the arid zone that occurred between 1940 and 1960 (Finlayson 1961; Burbidge *et al*. 1988). This phenomenon is believed to be due to several factors including a widespread change in fire regime following the demise of the nomadic lifestyle of the Aboriginal people, and the arrival of the fox. In 1982 numbats were found only in the southwest, at a handful of sites in jarrah (*Eucalyptus marginata*) forests and wandoo (*E. wandoo*) woodlands south and east of Perth, in *Banksia* woodland on the Swan coastal plain and in one area of jarrah forest east of Manjimup (Perup).

The rapid progress of land clearing between 1945 and 1970 greatly reduced available habitat in the wheatbelt of WA. In the mid 1970's, there was a dramatic decline in numbat sightings, with some subpopulations becoming extinct during this period, including colonies at Boyagin Nature Reserve near Brookton, in remnant bushland in the Pingaring area (including Dragon Rocks Nature Reserve) and at Tutanning Nature Reserve near Pingelly (Connell and Friend 1985; Friend 2008; see Figure 2).

By the mid-1980s the northern jarrah forest numbat populations were almost extinct; the most recent sighting was in 1985 east of Mundaring (K. Pollock, pers. comm.). Surveys in 1992 failed to locate numbat subpopulations in the northern jarrah forest, and there have been no sightings of numbats on the coastal plain since 1985.

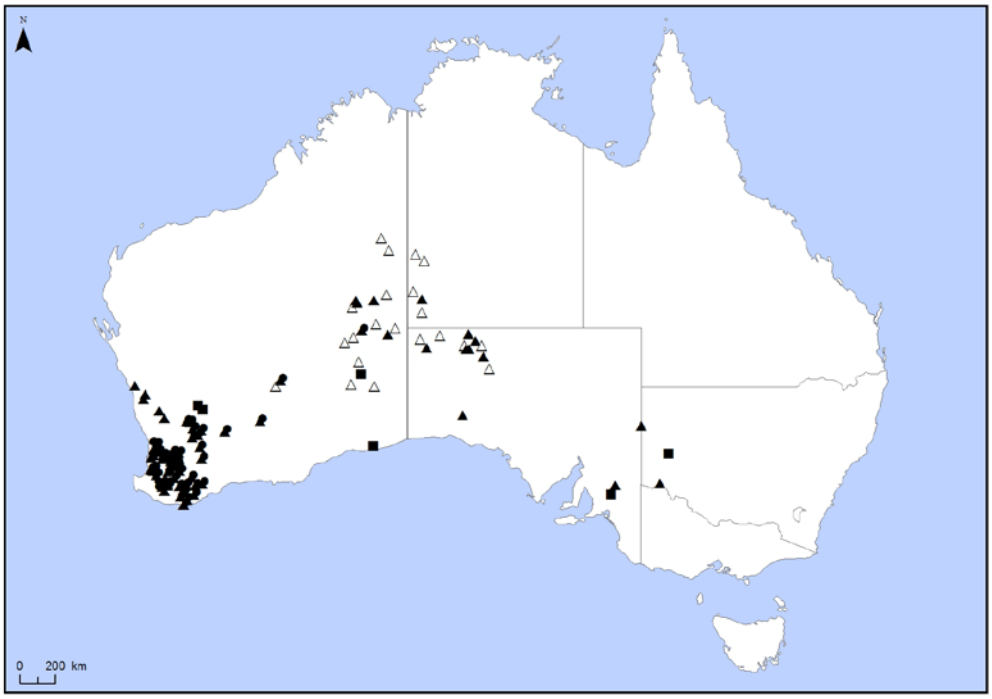

Figure 1: Historic recorded locations of the numbat. Circles: museum specimens collected alive. Squares: recent bone deposits. Closed triangles: literature records without specimens. Open triangles: information from Aboriginal people (Friend *et al.* 1982; Burbidge *et al.* 1988).

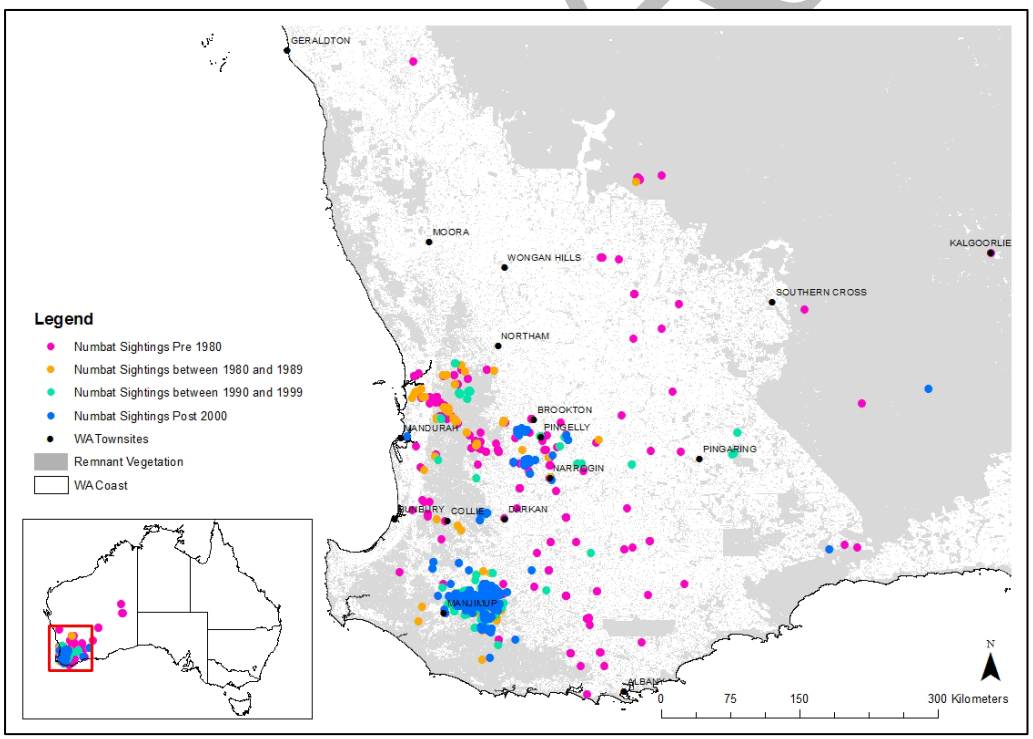

Figure 2: Numbat records in Western Australia, including museum specimen records, literature records and sighting reports (based on records in Department of Parks and Wildlife's Fauna Databases). Translocated subpopulations are included.

Current

The only remaining original numbat subpopulations are at Dryandra Woodland (150 km south-east of Perth) and the Upper Warren area (including Tone Perup Nature Reserve, Greater Kingston National Park and adjoining State Forest) (280 km south-south-east of Perth) (Figure 3).

Since 1985 there have been translocations of the numbat to 12 different sites within its former range, including three sites outside of WA (Table 1; Figure 3; Section 9.3). These can be grouped on the basis of an assessment of their "success" in terms of maintaining a self-sustaining subpopulation. In this context, "self-sustaining" is defined as persisting at least five years after the most recent release, apart from exchanges for genetic management. Of the 12 reintroduction sites, six have self-sustaining subpopulations, expanding the current distribution of the species in the jarrah forest and wheatbelt in WA, and into South Australia and New South Wales (Table 1).

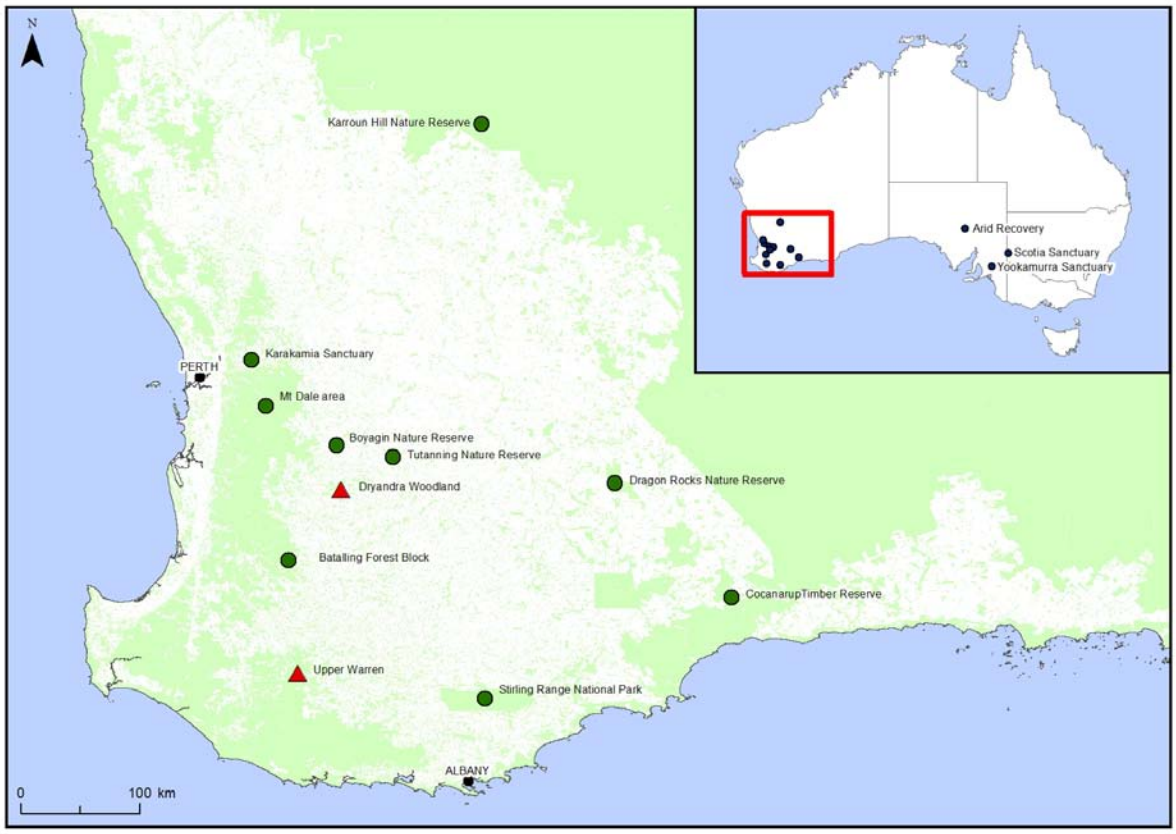

Figure 3: Numbat subpopulation sites, including all translocation sites. Original subpopulations are shown as red triangles and Western Australian translocation sites as green circles. Cleared land is shaded white; remnant vegetation is shaded pale green.

Table 1: Status and monitoring information for numbat subpopulations at the two original sites and the 12 translocation sites.

Site	State	Original / Reintroduced	Year of initial translocation	Latest release	Recently monitored?	Regularly monitored?	Self-sustaining?	Decline in last 5yrs?	Population estimate
Dryandra Woodland	WA	Original	-	-	Yes	Yes	Yes	Yes	50-100
Upper Warren	WA	Original	-	-	Yes	Yes	Yes	No	>100
Boyagin Nature Reserve	WA	Reintroduced	1985	2010	Yes	Yes	Yes	No	50-100
Karroun Hill Nature Reserve	WA	Reintroduced	1986	1993	No	No	No	No longer present	0
Tutanning Nature Reserve	WA	Reintroduced	1990	2005	Yes	Yes	Yes	Yes	<50
Batalling forest block	WA	Reintroduced	1992	2013	Yes	Yes	Yes	No	50-100
Yookamurra Sanctuary, SA	SA	Reintroduced	1993	1993	Yes	Yes	Yes	No	<50
Karakamia Sanctuary	WA	Reintroduced	1994	1999	Yes	Yes	No	No longer present	0
Dragon Rocks Nature Reserve	WA	Reintroduced	1995	1996	Yes	No	Yes	Yes	<50
Mt Dale Area	WA	Reintroduced	1996	1998	No	No	No	No longer present	
Stirling Range National Park	WA	Reintroduced	1998	2002	Yes	No	Status unknown	Yes	Unknown
Scotia Sanctuary, NSW	NSW	Reintroduced	1999	2012	Yes	Yes	Yes	No	>100
Arid Recovery, SA	SA	Reintroduced	2005	2005	Yes	Yes	No	No longer present	0
Cocanarup Timber Reserve	WA	Reintroduced	2006	2010	Yes	Yes	Status unknown	Yes	Unknown

1.5 Population trends

There are estimated to be less than 1,000 mature numbats in the wild and less than 250 mature individuals in the largest subpopulation (Friend and Burbidge 2008). Of the ten sites where numbats are known to be persisting, eight are considered self-sustaining. However of these eight self-sustaining subpopulations, five are considered to have declined in the past five years. As such, the overall trend for the species is considered to be an ongoing decline (Woinarski *et al.* 2014).

Original subpopulations

Dryandra Woodland

Numbat population levels at Dryandra in the 1950s were relatively high (sighting rates of 2-4 per 100km) (J. Calaby, pers. comm.) in comparison to the late 1970s when they were approximately one tenth of this figure, the lowest sighting rates being recorded in 1979 (Friend 1990). Fox control by baiting commenced in a 2000 ha experimental area in 1982 and was extended to 12,300 ha in 1989. During this time the population grew rapidly and peaked in 1992, at 11 sightings per 100km over a set transect. A year later this sighting rate had fallen to approximately half. There was no obvious new influence on the population at this stage and it appeared that the population outstripped the carrying capacity of the habitat. Although numbats (predominantly subadults) had been removed from Dryandra for the translocation program since 1985 (at a rate of 8-34 animals per year) the sighting rate had continued to climb through this period. Rates of predation of radio-collared numbats had not increased dramatically and animals captured in spring were in good condition. However, high numbat densities may have reduced food availability at other times of year. The demographic effect of a fatal infestation by an acanthocephalan parasite recorded in a number of numbats at Dryandra at this time is unknown but this disease condition may have been a factor in the decline (Haigh 1994; Smales 1997; Haigh and Friend, 1999).

The numbat subpopulation at Dryandra has not recovered to the high numbers of 1989-1993 despite the low level of removals (0-9 animals per year) for translocation and captive breeding since 1998. After the crash of 1993, sighting rates fluctuated between 2 and 4 per 100 km until 2007. Since 2008 there has been a further decline with 0.3 sightings per 100 km recorded in 2011 and 1.1 per 100 km in 2012. Research at Dryandra between 2011-2013 demonstrated that feral cats were a major cause of numbat predation (J.A. Friend, unpublished data). In 2011 research commenced to examine the effectiveness and non-target effects of feral cat baiting using Eradicat® baits in Dryandra.

In late 2014, 18 numbats were translocated from the captive breeding program at Perth Zoo to Dryandra woodland, in an attempt to reinforce the subpopulation. The fate of all the released numbats is not known but four were confirmed predated by native predators (pythons and raptors) and one by a cat (J.A. Friend, pers. comm.).

Upper Warren

Numbat sighting rates in the Upper Warren area reached very low levels in 1975 (Christensen 1980), corresponding to the low levels reached at Dryandra Woodland in the late 1970s (Friend 1990). Quantitative monitoring of the numbat subpopulation at Perup Nature Reserve by driven survey requires more effort than at Dryandra Woodland because the denser habitat restricts visibility and reduces sightability. Driven surveys were carried out in 1995 and 1996 to establish a baseline at the commencement of aerial baiting, recording sighting rates of 0.3/100 km and 1.45/100 km respectively. Driven surveys have been carried out in the Upper Warren (specifically in the Tone Perup Nature Reserve and adjacent Greater Kingston National Park) by Department of Parks and Wildlife Donnelly District since 2004 but sighting rates have been lower or zero (I. Wilson, pers. comm.). Opportunistic sightings are currently recorded through the Donnelly District office at Manjimup. These sighting reports have indicated that the numbat has extended its range in the area since the mid-1990s and is now found from the Southwest Highway in the west to the Lake Muir area in the south. The area of occupancy here exceeds 100 000 hectares and this area is now the stronghold of the species. There have been no recent removals or additions of numbats in this area. Numbats have been sighted within the Perup Sanctuary, a fenced area built in 2010 to protect a woylie colony by excluding foxes and feral cats from 420 hectares of jarrah forest in the Tone-Perup Nature Reserve. While numbats inside are probably able to pass through or over the 2m high fence, the enclosure will protect a small number of animals from fox and feral cat predation.

Translocated subpopulations

The increase in numbat numbers in the baited area at Dryandra in the early 1990s provided the opportunity to capture animals from Dryandra to provide stock for the establishment of additional subpopulations. Since 1985, numbats have been translocated to 12 different sites within the former range of the species (Table 1). Criteria used for selecting sites included their proximity to Dryandra, soil and vegetation types, available habitat, size and strategic position, termite abundance and predator control. Regular fox baiting under Department of Parks and Wildlife's Western Shield Wildlife Recovery Program is carried out at all Department of Parks and Wildlife-managed numbat translocation sites in Western Australia (commencing at varying times since 1984). All other sites chosen have long term feral animal control (e.g. fenced feral-free areas at Yookamurra, Karakamia, Scotia and Arid Recovery).

Translocated subpopulations assessed as self-sustaining

Boyagin Nature Reserve

Boyagin Nature Reserve was selected for the first experimental translocation commencing in 1985, because of its proximity to Dryandra and similarity in soils and vegetation (Friend 1990, Friend and Thomas 1994). Boyagin Nature Reserve comprises two blocks, totalling 5000 ha, separated by 500m of farmland. Thirty-five founder animals were released into the east block between 1985 and 1987. Although some radio-collared animals were lost to predation, breeding was recorded. In 1992 numbat diggings were first found in the west block, signifying migration from the east block. The sighting rate in driven surveys had risen to 5.5/100 km by November 1993. In 1995 the sighting rate in the west block exceeded the rate in the east, and both blocks now support self-sustaining subpopulations. This reserve has the capacity to support around 200 established adults (Friend 1990). A male and a female were transferred from Boyagin as part of the translocation to the Mt Dale Area in 1997. In addition, individual animals have been transferred each year from Boyagin to the Perth Zoo breeding colony in 2010, 2011 and 2012.

In order to improve the genetic health of the subpopulation, two additions of individuals of Dryandra stock (a male and a female in 2005 and a male and a female in 2010) have been carried out since the original translocation.

Batalling

Batalling is a State forest management block containing jarrah forest and wandoo woodland at the eastern edge of State forest near Darkan. Fox control by baiting has been carried out there since 1990. The current fox baiting regime is six times per year with aerial baiting, supplemented by monthly ground baiting along a route through the core area. Timber harvesting and regeneration burns have been carried out in the adjacent blocks Hillman and Godfrey blocks since the late 1990s. Sixty numbats (46 wild-caught at Dryandra and 14 captive-bred) were released at Batalling over the years 1992-1995. The main difficulty encountered was the disappearance of animals after release. The forest extends 50 km west and 200 km north of the release site and although all forests within 25 km of the release site was thoroughly searched by aircraft for radio-collared animals, over half of the numbats released were never located again. It is likely that many animals dispersed well beyond the search area. Monitoring by searching for diggings has revealed that numbats persist at a number of sites in the area. The most recent intensive diggings survey was carried out in 2004, and numbat signs were located at six locations within 10 km of the release site, in Batalling, Hillman and Godfrey blocks. Locations of 12 sightings since then have all been consistent with the 2004 diggings survey and together these indicate a stable area of occupancy of around 4000 hectares. A short diggings survey was carried out in November 2013, locating numbat signs in two places within this area.

Supplementation to improve the genetic health of the Batalling subpopulation were carried out with the release of four captive-bred numbats of Dryandra stock in 2005, four in 2010 and nine in 2013.

Tutanning Nature Reserve

Tutanning Nature Reserve (2000 ha) is located 45 km north-east of Dryandra and was the site of the third experimental reintroduction. This reserve was chosen on a trial basis as it was considered close to the minimum area able to support a self-sustaining numbat subpopulation. This reserve contains remnant vegetation surrounded by cleared farmland, and there has been no evidence of an original numbat population there since 1985. Fox-baiting has been in place since the mid-1980s, and the reserve is currently ground-baited monthly. Between 1990 and 1996, 32 numbats were translocated into the reserve, mostly wild-caught from Dryandra but including six captive-bred individuals from Perth Zoo and one site-bred animal from Karakamia. Monitoring radio-collared animals revealed that they established home ranges in powderbark (*Eucalyptus accedens*) and wandoo (*E. wandoo*) woodlands (Friend and Thomas 2003). Driven surveys commenced in 1996 and were carried out in April annually or biennially until 2004. Small numbers of numbats were sighted during most surveys indicating that a self-sustaining subpopulation was established at Tutanning. Three captive-bred numbats were released at Tutanning in 2005 to improve genetic health. The most recent reported sightings were in 2009 (B. Macmahon, pers. comm.) and separate camera-trap surveys in 2013 by J.A. Friend (pers. comm.) and N. Thomas (pers. comm.) captured images of several numbats. Intensive survey at Tutanning is required to determine the status of the subpopulation.

Yookamurra Sanctuary

Yookamurra Sanctuary (5108 ha) is located near Sedan in the Murray Mallee area of South Australia and was established by Earth Sanctuaries Limited. 1092 ha of remnant mallee woodland and associated vegetation is surrounded by an electrified fence, completed in 1992 and declared free of foxes, feral cats and rabbits the next year. Following a habitat assessment, 15 numbats from Dryandra were captured and transported to Yookamurra in late 1993. These animals were all radio-collared before transfer and released into hollow logs on the day after capture (J. A. Friend, pers. comm.). Three animals were taken by birds of prey within two weeks of release, and another died as a result of the presence of an acanthocephalan parasite (Haigh 1994). However the subpopulation became established and high sighting rates (10/100 km) were reported by 1996. The subpopulation grew to the extent that 19 animals could be removed in November 1999 for translocation to Scotia Sanctuary, followed by another 24 one year later (L. Pope, pers. comm.). In addition, eight numbats were transferred from Yookamurra to Western Australia for release in the Stirling Range National Park in December 1999 as part of the numbat reintroduction in progress there (Friend and Thomas 2003).

In 2002 Yookamurra Sanctuary was acquired by Australian Wildlife Conservancy. After several incursions of foxes, the fence was modified in 2006, with no incursions since. Driven surveys in 2003 recorded a numbat sighting rate of 3 per 120km). The numbat subpopulation is monitored annually by driven survey. The most recent survey, in December 2013, resulted in a sighting rate of 8.7 per 100 km (A. Carter, pers. comm.). This was a dramatic increase over the 2009 rate of two sightings in over 900 km driven.

Dragon Rocks Nature Reserve

Dragon Rocks Nature Reserve (33 000ha), in the eastern wheatbelt 190 km east of Dryandra, is a large remnant of native vegetation in an otherwise largely cleared landscape. Twenty numbats were translocated from Dryandra in December 1995 and 17 in December 1996. Survival rates were high and 10 and 27 site-bred young were captured in 1996 and 1997 respectively. The release program at Dragon Rocks was curtailed after only two years because of the high number of numbats known to be present in the reserve in 1998.

Limited monitoring at this remote sitesince 1998 has mainly been by diggings searches and a survey in June 2000 which revealed the presence of numbats at 14 separate locations within the reserve. A broader survey in September 2003 also found signs of numbat presence widely distributed across the reserve, indicating that the subpopulation had achieved self-sustaining status. More recently, numbat sightings were reported by reliable observers in 2008 and 2009. Although a three-day search for numbat signs at Dragon Rocks NR in December 2012 failed to find any evidence of persistence. A camera-trap survey in June 2013 captured an image of a numbat within the Nature Reserve. During the same trip, a neighbouring property owner reported sightings of numbats in the reserve in the previous 12 months.

Scotia Sanctuary

Scotia Sanctuary (65 000 ha) was established by Earth Sanctuaries Limited in 1994 and purchased by Australian Wildlife Conservancy in 2002. It is located in south-western New South Wales, on the South Australian border approximately 100 km north of the Murray River. Stage 1 is a 4000 ha fenced, feral free area in the northern part of the Sanctuary. Ten numbats were translocated into Stage 1 from

Yookamurra Sanctuary in November 1999. These animals were fitted with radio-collars and their survival and habitat use monitored. After two weeks there were no casualties so a further nine numbats were translocated from Yookamurra. Survival was very good, with 80% of the released animals surviving the first year.

A further 24 numbats, again sourced from Yookamurra, were released in November/ December 2000. Monitoring during 2002 indicated that the subpopulation was expanding. After the acquisition of Scotia by AWC in 2002, the predator fencing was entirely replaced with a higher fence of different design. In 2006, a study of habitat use and numbat density was carried out in Stage 1. Driven survey recorded 2.76 sightings/100km and produced a conservative subpopulation estimate of 50-69 individuals (Viera *et al*. 2007).

While a natural process, predation by native predators may become significant to the recovery of the numbat when numbat population density is low, and alternative prey is also low. This appears to be accentuated with the release of predator-naïve captive bred animals.

In 2008, a second 4000 ha fenced area was declared free of foxes and feral cats. Seven numbats were transferred from Stage 1 into Stage 2 during December 2009. Three more were transferred in November 2011. In December 2011 one wild-caught (Dryandra) and 12 captive-bred numbats from the Perth Zoo breeding colony were translocated to Stage 2. Within a month, eight of these had died, with some evidence of predation by brown goshawks. In December 2012 another 17 captive-bred numbats were transferred from Perth Zoo to Stage 2. Eleven were fitted with radio-collars: seven had died within a month, some through avian predation but others showing evidence of starvation. This release had occurred following two years of low rainfall.

In November 2005, five numbats were moved from Scotia Stage 1 to the Arid Recovery reserve at Roxby Downs in a trial translocation (see below). In December 2008, an adult male numbat was transferred from Scotia to Perth Zoo to enhance the breeding program, followed by three more adult males in November 2012.

The Scotia numbat subpopulations have been monitored annually by driven surveys in Stage 1 during November/ December, and by track (footprint) surveys in Stages 1 and 2 (up until 2012). Recent survey results (January 2014) in Stage 1 returned an average sighting rate of 5.64 numbats per 100 km (F. L'Hotellier, pers. comm.). Survey methodology is currently under review to determine the most appropriate methods.

Translocated subpopulations assessed as Status unknown

Stirling Range National Park

The Stirling Range National Park (115 920 ha) is a large area of remnant vegetation dominated by the Stirling Range but incorporating broad plains and foothills surrounding the range. Fourteen numbats, including 10 from Dryandra and four adult animals from the Perth Zoo colony, were released in wandoo woodland in the western section of the National Park in December 1998. Despite frequent bushfires in this national park, much of this part of the park had escaped unburnt for over 20 years. Subsequent releases involved some animals translocated from Dryandra and some from the reintroduced subpopulation at Yookamurra (1999) but the majority were from the captive breeding colony at Perth Zoo (2000-2004). Numbats were released each year from 1998 to 2005. A total of 88

animals were released, comprising 15 wild-caught from Dryandra, 8 wild-caught from Yookamurra and 65 captive-bred from Perth Zoo. Twenty-three site-bred young were captured and radio-collared during this time. The greatest number of recorded mortalities was from predation by birds of prey. In 2000, Perth Zoo implemented an experimental training program whereby young captive-bred numbats are exposed to a raptor, while loud noises and bird alarm calls are sounded in an attempt to train captive bred animals to be predator aware. A comparison between trained and untrained numbats indicated that trained animals had a higher survival rate over the first five months after release than untrained animals (J.A. Friend, unpublished data.).

Diggings searches carried out in 2008 showed that numbats were still present in the national park but it is unknown whether this subpopulation is self-sustaining. An extensive diggings survey is required to determine its status.

Cocanarup Timber Reserve

Cocanarup Timber Reserve (5452 ha), located 11 km west of Ravensthorpe, was originally set aside for timber supply (especially fence posts). It is set within a much larger area of uncleared land, currently unallocated Crown land but proposed as State forest and nature reserve. This area, surrounding the upper Phillips River valley, includes significant stands of salmon gum (*Eucalyptus salmonophloia*), swamp yate (*E. occidentalis*) and jam (*Acacia acuminata*). Salmon gum and yate provide plentiful hollow logs and support good termite populations. Fox control by quarterly aerial baiting has been carried out here since 1997 and ground baiting has been carried out monthly since 2006. Fifty-two numbats (39 captive-bred from Perth Zoo and 13 wild-caught from Dryandra) were released at the site between 2006 and 2009. All numbat home ranges were recorded by radio-tracking and were located within the wooded areas near the river and its tributaries, rather than in the surrounding low scrub. Breeding was recorded each year from 2007 to 2011, but survival of young was poor, with only one site-bred animal captured. Birds of prey caused most predation of released animals with chuditch and carpet pythons accounting for a few. The most recent reported sighting was in January 2013. The status of the subpopulation will be assessed by diggings searches and camera-trap surveys.

Translocated subpopulations assessed as not self-sustaining

Karroun Hill Nature Reserve

Karroun Hill Nature Reserve (300,000 ha) is located 320 km north of Dryandra and was chosen for the second experimental translocation because of its large size and strategic position on the edge of the vast expanse of uncleared land east of the agricultural zone, including the Great Western Woodland. The previous existence of the numbat was recorded here by Youngson and McKenzie (1977). Vegetation, soils and climate differ markedly from those at Dryandra, and this site was used to test whether reintroduction procedures developed at Boyagin would be successful in such a different environment. The baiting regime developed from a pre-existing aerial baiting program to control dingoes, to an aerial baiting program twice a year with fox baits over a 40,000 ha area around the release site in 1990, then increased to quarterly aerial baiting in 1996.

Ninety-seven numbats were released at Karroun Hill between 1986 and 1993, all translocated directly from the wild at Dryandra. Forty-three young born at the site were captured during monitoring trips (Friend and Thomas 1994). A subpopulation became established and numbat signs were plentiful, particularly in woodlands dominated by *Callitris columellaris* with dense scrub nearby. In October

2000, seven years after the last release, fresh numbat signs could be found in this vegetation type. Searches of the baited area in October 2001 and January 2002 revealed widespread but old numbat signs (weathered scats) and no fresh diggings, indicating a rapid subpopulation decline during the previous year or two. The most recent search, in September 2003, produced a similar result. It is unlikely that numbats survived in the reserve., and aerial baiting ceased in March 2002.

Karakamia Sanctuary

Karakamia (280ha) is a fenced sanctuary established in 1993 by Martin Copley (founder of the Australian Wildlife Conservancy) in jarrah-marri forest 40 km northeast of Perth. Three radio-collared numbats (a male and two females) were released in the sanctuary in December 1994 and established home ranges. The sanctuary is considered too small to support a viable numbat subpopulation and its management would need to involve supplementation and removal of individuals to counter stochastic loss of the subpopulation and to reduce inbreeding. The colony was supplemented with a male numbat in 1996 and a male and a female in 1999, all from Dryandra. Young were produced on at least four occasions and one young male was translocated to Tutanning in October 1995. In December 2002 a mature male was translocated to Perth Zoo. More recently retired individuals from the breeding program have been released at Karakamia for education purposes only. No numbats are known to currently exist at Karakamia.

Mt Dale Area

The Mt Dale Area (5798 ha), approximately 45 km south-east of Perth, was selected as a translocation site in 1996. It is now part of Helena National Park and consists of jarrah and jarrah-marri forest on ridges and slopes, with wandoo and wandoo-marri woodland in the valley floors. The area is centrally located between the eastern and western borders of the northern jarrah forest and is surrounded by suitable numbat habitat that is subject to fox control. It was seen as a strategic release site that would provide an establishing subpopulation with the ability to expand into adjacent suitable areas.

The translocation commenced in December 1996 when the area was being baited twice a year as part of research on varying baiting regimes . Twenty numbats from Dryandra were released into hollow logs at a jarrah upland site near Mt Dale. This group of numbats dispersed across the width of the forest belt with individuals reaching the eastern and western extremes of the forested area some 50 km apart. No numbats remained near the release site. The animals that survived and established home ranges settled in wandoo valleys north-east of Mt Dale and this area was used for the second and third releases. Coincidentally, the new release site was near the location of a numbat sighting in 1985 (K. Pollock, pers. comm.), the last recorded from the northern jarrah forest prior to the local extinction. In all, 61 numbats were released between 1996 and 1998 (44 wild-caught from Dryandra, two wild-caught from Boyagin and 15 captive-bred). Breeding was recorded, and eight site-bred young were captured in 1999.

Monitoring by radio-tracking ceased in 2001, when no radio-collared numbats remained. A hazard reduction burn planned for the Nockine block, immediately north of the second release site prompted a search for diggings and scats in September 2003. Searches of 15-30 minutes in duration were carried out at 500m intervals along 25 km of the track network, concentrating in the wandoo valleys, extending up to 300m from the track. No diggings were found (Friend and Thomas 2003). More recent searches, including one in 2009, have also failed to find any evidence of numbats persisting.

Arid Recovery

Arid Recovery is a privately managed reserve established in 1997 in association with the Olympic Dam uranium mine, centred around a 12,300 ha fenced area. Feral predators have been eradicated from a 6000 ha area. In November 2005, five numbats were translocated from Scotia into the Arid Recovery reserve as part of a trial to investigate the suitability of the reserve for a full-scale reintroduction. Two males were still alive 18 months after release; the other three were taken by birds of prey in the first seven months. During this trial, mean home ranges were estimated at 67 ha in summer and 25 ha in autumn/ winter and animals were observed to use burrows rather than hollow logs (Bester & Rusten 2009). Further trials with greater numbers are planned to determine whether females are able to wean young, and whether Arid Recovery is able to sustain a viable subpopulation.

1.6 Biology and ecology

Reproduction and dispersal

Knowledge of the reproductive ecology of numbats is largely due to research in Dryandra Woodland since 1981 (e.g. Friend & Burrows 1983; Friend 1996; Friend, unpublished data). Production of young is a highly synchronised event; at Dryandra all young are born in January or early February, and most in the second half of January. Development of the young while attached is relatively slow compared with other marsupials. The female deposits her young in a nest (usually in a burrow) in late July and continues to suckle them each night. In early September, the young come to the entrance of the burrow each morning after the female has emerged, often before she departs to forage. During the first week or so, they do not move more than a few centimetres from the mouth of the burrow, but subsequently make longer excursions. By mid-October the young numbats are supplementing their mother's milk with termites that they dig up for themselves, and moving up to 100 metres from the nest though still in their mother's home range. The female often moves her litter to a succession of nests in logs, trees or other burrows, particularly after the loss of any young to predators.

In November, some young start to nest away from the mother and their siblings, within the maternal home range. Later that month or in early December, all young leave their maternal home range and disperse. The dispersal movement is quite rapid, rarely taking more than a week from departure to establishment in the area where the numbat will spend the rest of its life.

Dispersal appears to take place as straight-line movements, while the animal is moving through the bush. A dispersing juvenile numbat at Dryandra was followed over several days, during which time it moved four kilometres from its natal area straight to the edge of farmland. It then moved along the forest-farmland boundary for two kilometres before reaching the area in which it established its home range. Radio-tracking of dispersing numbats has shown that they rarely cross farmland, but often end up in suitable habitat at the edge of cleared land. This evidence indicates that the farmland-forest interface is a barrier for dispersing numbats.

Females breed in their first year, while males do not become sexually mature until their second year. From September, established males begin to move outside their winter home ranges. At this stage, the male pre-sternal gland becomes active, exuding an oily liquid that stains the animal's ventral surface red-brown. As the height of the mating season approaches, the male's testes enlarge as they

begin to produce sperm, reaching a peak in late December. The male cloacal region swells noticeably with the associated glandular enlargement. By January, male numbats are ranging widely and traversing the home ranges of a number of females.

Females come into oestrus during January. In captive animals, the onset of oestrus has been established by monitoring the sudden increase in epithelial cells in the urine. If mating does not occur in the following 48 hours, young are not produced. Power *et al*. (2009), recorded polyoestry in captivity, female come into oestrus again about 25 days after an earlier unsuccessful mating. The gestation period is 14 days, after which up to four young are born, pink, hairless and measuring about 10 mm in total length, and attach themselves to the four teats (Friend & Whitford 1988, 1993).

The greatest longevity observed in the wild so far is 5 years although most numbats do not achieve this age.

Diet and foraging

Many of the characteristic features of the numbat are a result of its adaptation to a specialised diet of termites (*Isoptera*). While ants (*Formicoidea*) are also taken, there is little doubt that the feeding activity is essentially a hunt for termites. Numbats show no strong preference for any species of termite, taking each species roughly in proportion to its abundance (Calaby 1960).

Numbats appear to spend much of the day feeding, and observations of captive animals show that each individual consumes up to 20 000 termites each day (Friend 1985; Friend 1994; Cooper and Withers 2004). This corresponds to approximately 10% of the body weight of an adult animal. At Dryandra termites occur in mounds, in tree-trunks or underground from where their subterranean feeding galleries spread out. Numbats intercept termites in these feeding galleries, rather than in the nests, exposing them by digging in the upper 50 mm of the soil, by turning over small pieces of dead wood and by scratching bark and decayed wood from old logs, stumps and fallen trees limbs (Calaby, 1960, Christensen *et al*. 1984).

Activity period

A feature that sets the numbat apart from almost all other marsupials, and other Australian terrestrial mammals, is its strictly diurnal nature. Although their daily activity pattern changes during the year, numbats do not emerge from their night refuges until well after dawn, and return to one of their nests before dark. In summer, numbats are active throughout the morning, but there is a period of inactivity between midday and late afternoon, followed by an active period before dusk. In winter, there is only one active period, of between four and six hours from mid-morning to mid-afternoon. This pattern of activity corresponds closely to the availability of termites in the upper soil layers, as these insects respond to the temperature of this environment (Friend 1985).

Refuge and nesting requirements

Numbats use hollows and burrows for a number of different purposes. These include nesting at night, resting during the day and as refuges when under threat of predation. When the young are too large to be carried by the mother on her daily foraging trips, they are left in nests, hollows or burrows during the day, and suckled there at night. In areas that lack logs or in the summer months; some numbats rest during the day under shrubs and fallen foliage. They sometimes take refuge from threat

under this kind of cover, but there has been no record of numbats nesting at night in such a position. Nests are made in hollows with only one entrance and an internal diameter of 60-80 mm. Hollows in trees, up to 5 metres above ground are used as well as hollow logs on or near the ground.

Numbats construct their own burrows. A typical burrow consists of a single, gently sloping shaft 1-2 metres long widening out into a roughly spherical, terminal chamber about 25 cm in diameter. A nest fills the chamber and consists of readily available plant material such as grass, leaves or shredded eucalypt bark (Glauert 1935; Christensen 1980; Friend & Burrows 1983; Christensen *et al.* 1984). Both males and females dig burrows and these are used particularly in winter. Nests of similar materials are also made in nest logs.

Movements and social organisation

Numbats are solitary and territorial. They occupy home ranges which are exclusive of other individuals of the same sex. Once a juvenile numbat has established its home range after dispersal, that animal remains in or close to that area for the rest of its life.

The male pattern of adjacent home ranges overlaps the female pattern. Although use of habitat by each sex changes during the year (females contract their area of movement in summer, males in winter), the overall result is that there is approximately one pair of established adults per 50 ha in high-quality habitat. These data were obtained by radio-tracking 15 numbats in wandoo woodland in Dryandra and Boyagin Nature Reserve (Friend unpublished data), but the results of tracking two numbats in Tone Perup Nature Reserve indicate a home range size of the same order in jarrah forest (Christensen *et al.* 1984). Radio tracking of newly translocated numbats in arid South Australia also indicated similar home ranges of 67 ha in summer and 25 ha in autumn/winter (Bester & Rusten 2009).

2. Habitat critical to survival and important subpopulations

Numbats have historically been present in a large variety of habitat types, including eucalypt forest, eucalypt woodland, *Acacia* woodland and *Triodia* grassland. Because they now only exist in a small proportion of the range of habitat types previously occupied by the species it is not possible to provide an exhaustive description of characteristics of habitat critical to their survival. However, some key characteristics consistently occur in areas where subpopulations currently exist or historically existed and these include:

- Presence of termites in sufficient abundance - all evidence relating to the diet of the numbat throughout its range indicates an almost complete dependence on termites (Calaby 1960).
- Presence of eucalypt species - the majority of sites where numbats occur and were recorded in the past are characterised by the presence of eucalypt species thus providing logs and hollows and possibly higher termite densities. An exception to this may be the apparent existence of numbat subpopulations in *Triodia* tussock grasslands of the arid zone, but these may have relied on proximity to woodland patches.
- Sufficient cover - adequate cover near ground level is required to provide refuge from predators. Cover may be provided by thickets or a combination of thickets and hollow logs.
- Sufficient openness - although a degree of cover is required for refuge from predators, a sufficiently open understorey is required for feeding sites. A combination of an open understorey interspersed with thickets and hollow logs is considered ideal.

Incorporation of management practices such as the retention of logs and hollows during timber harvesting and burning operations, and implementation of introduced predator baiting programs are also important to the conservation of the numbat.

Numbats need large areas of natural woodland vegetation because of their relatively large home ranges and limited food resources. Habitat that allow for natural expansion of the species distribution and habitat linking existing subpopulation are also considered critical. Areas that do not currently contain the species, but did so historically, and are suitable for translocation now or in the future if threat abatement occurs should also be considered important.

All current subpopulations are considered as important and necessary for long-term survival of the species. Particular attention should be given to the original subpopulations and to ones sufficiently large to be considered self-sustaining or that have the potential to become self-sustaining.

3. Threatening processes

Like many medium-sized Australian mammals, the numbat has suffered an extensive decrease in range and population numbers since European settlement. Historic declines have been associated with altered fire regimes, predation by introduced mammals and clearing for agriculture (Friend 2008).

The threats outlined in this section relate to established, self-sustaining numbat subpopulations only. Threats to animals immediately after reintroduction are distinct from threats that affect the long-term survival of the subpopulations, as animals are particularly vulnerable at this time. For example, raptor predation may be a threat to the successful establishment of a self-sustaining subpopulation but is probably not an ongoing threat once these subpopulations have established. However, although the species may be adapted to this predation pressure under normal circumstances, recent modifications of processes such as fire may lead to an increase in this predation pressure and a subsequent subpopulation decline.

3.1 Predation by the fox

The contraction of the numbat's range generally followed an east to west pattern and became more rapid when the introduced fox expanded westward, following the colonisation by rabbits from south-eastern Australia (Friend 1990). This is a strong indication that fox predation was responsible for the decline of numbats (Kinnear *et al.* 1988) (Friend 1990). However, numbats are difficult to monitor as they do not respond to conventional trapping techniques. Caughley and Gunn (1996) suggested that the fox may have been overemphasised as a limiting factor on numbat populations. Regardless, the body of evidence indicating the beneficial effect of fox control on medium-sized mammal populations (e.g. Morris *et al.* 1995; Kinnear *et al.*1998) is now extensive and includes the success of many reintroductions of the numbat (Friend and Thomas 2003) and other Critical Weight Range mammals (Burbidge and McKenzie 1989) into areas under fox control (Morris 2000; Kinnear *et al.* 2002; Groom 2010).

All of the current known (original and translocated) subpopulations in Western Australia are in areas subject to fox control, however this does not mean they are completely protected from fox predation as complete eradication of foxes outside fenced enclosures is not achievable. It is important that fox control practices are given high priority, are well monitored and that techniques continue to improve. Translocated subpopulations in South Australia and New South Wales are in fenced enclosures that generally exclude foxes and feral cats and this should afford a higher degree of protection from this threat.

3.2 Predation by feral cats

The impact of feral cat predation on the long-term persistence of numbat subpopulations is unknown. Feral cats were identified as predators of numbats at several translocation sites (particularly Karroun Hill). However, relatively few predation events could be definitely attributed to feral cats and these were only recorded during the initial stages of translocation while animals were radio-monitored.

These predation events by feral cats were recorded at Karroun Hill soon after the commencement of aerial baiting. In other reintroduction programs at arid and semi-arid sites, feral cat numbers have risen in response to fox control (Christensen & Burrows 1994; Short *et al.* 1994). However, between 1986 and 1993, when numbats were monitored by radio-tracking, raptors were responsible for more predation of numbats than were foxes or feral cats, probably as a result of the general lack of cover (Friend and Thomas 1994).

Preliminary results of a research program currently being carried out at Dryandra, points strongly to predation by feral cats as a major cause of the recent numbat decline (Friend 2012). Forensic evidence, including analysis of DNA on radio-collars of predated numbats, showed that feral cats were responsible for the deaths of 9 out of 20 numbats taken by predators between January 2011 and November 2013 (J.A. Friend, unpublished data). The other 11 deaths were due to raptors (6), foxes (2), pythons (2) and chuditch (1).

The significance of predation by feral cats in regulating numbat subpopulations, as well as other fauna in areas where foxes are controlled requires urgent investigation and associated actions (Woinarski *et al.* 2014). There is evidence that cat abundance and predation pressure can increase in areas where foxes are controlled (Marlow *et al.* 2015).

All of the original subpopulations and most of the translocated subpopulations are subject to feral cat predation. The translocated subpopulations within fenced enclosures at Yookamurra and Scotia Sanctuaries are protected from feral cats. Experimental feral cat baiting using Eradicat® baits is under way at Dryandra and Tutanning (Friend 2012), as well as at a range of other sites across Western Australia (Algar and Mitchell, 2013).

3.3 Inappropriate fire regimes

Numbats are not generally considered to be affected directly by fire but loss of habitat cover post fire may increase mortality through exposure to predation, and their dependence on hollow logs for shelter and on debris-feeding termites for food means that the species is potentially vulnerable to fire in its habitat.

The impact of prescribed fire on the numbat habitat and subpopulations has been investigated experimentally in wandoo woodland at Dryandra (J.A. Friend unpublished data). The findings of this study were:

- death during the fire and competition from displaced animals were not significant threats
- all animals surviving fires remained in good physical condition, and all continued to use their pre-fire home ranges
- prescribed fire in Dryandra did not have a significant impact on the availability of termites for numbats, or on the numbats' nutritional status
- loss of cover, in the form of both logs and thickets, appears to increase mortality through predation
- spring burns can cause a greater overall loss of logs than intense autumn burns.

Long intervals between fires would increase cover from predators through increased development of *Gastrolobium microcarpum* thickets. Studies by Burrows *et al.* (1987) on these thickets at Dryandra indicated that autumn fires at intervals of 20-30 years would allow them to attain their maximum development. After that time, thickets degrade through senescence of individual plants and require fire for regeneration.

Regular prescribed burning of forest areas occurs within the Upper Warren. Fire management in this area recognises the importance of the area for threatened fauna species and burns are generally prescribed to be mild in intensity, create a finer scale mosaic of burnt/unburnt but also consider rotational seasonal elements to provide more intense fires every 20-30 years for regeneration of thickets. It has been observed that intense autumn burns cause a greater loss of logs than milder spring burns, in contrast with that reported to occur in Dryandra (B.Barton, pers. comm.).

In the South Coast region fire sensitive ecosystems have been identified in order to assist future land management and planning (Barrett *et al.* 2009). These are systems that are vulnerable to long term loss of species diversity, changes to vegetation structure and habitat value as a result of inappropriate fire regimes. Several woodland vegetation communities in that may provide suitable habitat for numbats are included.

3.4 Habitat disturbance and fragmentation

At present the numbat occurs in a number of isolated subpopulations. While most are sufficiently large to maintain self-sustaining subpopulations the maintenance of long-term genetic variability in existing and re-introduced subpopulations will rely on movement of animals between subpopulations. This can only occur through long-distance natural dispersal across cleared land, by way of habitat linkages or by artificial transfer of individuals. Numbats have been known to cross farmland but this appears to be rare, occurring mainly in times of high population density. While there are a number of projects supporting the establishment of large scale habitat linkages across highly cleared regions, none of those currently in place are likely to assist in dispersal of numbats between existing subpopulations. For the present, to achieve genetic transfer between subpopulations and recolonisation after local subpopulation extinction, artificial movement of individuals and translocations will be necessary.

Timber from the brown mallet (*Eucalyptus astringens*) plantations at Dryandra has been utilised for tool-handles, fence-posts and firewood. The harvesting operation involved the removal of selected large trees for tool-handles, then later removal of small trees for fence-posts. The plantation area was then opened for commercial and sometimes public firewood collection.

A study of movement and feeding activity of numbats in a mallet plantation before, during and after harvesting showed that in the area in which timber harvesting occurs, numbat usage decreases significantly during the harvesting operation, but returns to pre-harvesting levels when use of machinery and regular human activity in the area ceases (J.A. Friend, unpublished data). Radio-tracking showed that numbats actually leave the area being harvested, moving to other parts of their home ranges. This disruption lasts about six months during a typical operation.

While this industry was in operation, levels of mallet harvesting at Dryandra resulted in the disturbance of less than 10% of the total area of mallet plantation each year. The tool-handle and fence post operations have ceased, however, although commercial harvesting continues, over about 30-40 hectares per year.

Numbats occur in two other areas of State forest subject to selective timber harvesting; in management blocks adjacent to Batalling block and in the Upper Warren area. Numbats survived through timber harvesting operations carried out in Kingston during the 1990s, before its declaration as a national park, and they continue to persist in the logged areas today. Research to better understand the effect of timber harvesting on resident numbats and to further inform the development of the silviculture guidelines specifically for numbats is proposed under this recovery plan.

3.5 Disease

A number of potentially pathogenic conditions have been recorded in wild and captive numbats, but most are uncommon. These include fungal and bacterial infections and the presence of endoparasites. One endoparasite, an acanthocephalan (*Multisentis myrmecobius* Oligacanthorhynchidae (Smales 1997)), caused the death of several numbats at a time of very high population levels at Dryandra (Friend 1994; Haigh 1994; Haigh and Friend 1999). No numbat deaths since then have been attributed to this species. This acanthocephalan sheds very few eggs so it is very difficult to diagnose infection until acute effects occur. Infected animals with high acanthocephalan loads typically die from obstruction of the gut. As insects are the intermediate hosts of the Oligacanthorhynchidae the life cycle of this species probably involves termites (Smales 1997) and it may be that high numbat numbers at Dryandra in 1990s led to an increase in its occurrence in termites and a high infection rate in numbats.

As a result, all numbats translocated directly between reserves have been treated with an injectable broad spectrum anti-parasitic agent before transfer.

3.6 Climate Change

Climate modelling in the areas of south-western Australia currently occupied by numbats generally predicts warmer temperatures and lower rainfall (IOCI 2010). Given the former range of the numbat, which extended well into parts of central Australia with far hotter and drier climates than the south-west, it might be expected that the numbat is pre-adapted to some degree to warmer, drier climates. Their termite food is similarly arid-adapted and termites have strategies of exploiting ground water to maintain themselves between rainfall events. It is important, however, for the recovery planning process to be informed about the implications of climate change for threatened species.

4. International obligations

This plan is consistent with the aims and recommendations of the Convention on Biological Diversity, ratified by Australia in June 1993, and will assist in implementing Australia's responsibilities under that Convention. The species is not listed under the appendices to the United Nations Environment Program World Conservation Monitoring Centre's Convention on International Trade in Endangered Species (CITES), and does not affect Australia's obligations under any other international agreements.

5. Affected interests

Interests potentially affected by, or involved, in the implementation of this recovery plan include:

- State government agencies - Department of Parks and Wildlife, Environmental Protection Authority (EPA), Forest Products Commission (FPC), WA Planning Commission (WAPC);
- Perth Zoo;
- WA Museum;
- Commonwealth government Department of the Environment;
- Non-government conservation organisations – presently this includes Australian Wildlife Conservancy (AWC) and Arid Recovery. Other non-government conservation organisations such as World Wildlife Fund for Nature (WWF) may be involved in the future;
- Government agencies in other States – may be involved in future translocations;
- Local government authorities;
- Traditional owners and managers;
- Infrastructure providers – government and non-government providers of infrastructure including Western Power and associated providers, and Department of Water;
- Industry groups – government and private organisations and groups relating to mining exploration and mining operations, agriculture and timber harvesting may in the future have an interest affected by some recovery actions.
- Community groups – e.g. Project Numbat is a community organisation that aims to increase the profile of the numbat and raises funds for Numbat Recovery.

6. Role and interests of Aboriginal people

Department of Parks and Wildlife will consult with Aboriginal communities in the regions identified in this plan and ensure consideration of their role and interests in the implementation of this plan. Input and involvement will be welcomed from any Aboriginal groups that have an active interest in areas where the numbat occurs, and their involvement in recovery team representation will be sought. The Aboriginal Heritage Sites Register, maintained by the Department of Indigenous Affairs, will be used to identify significant sites near these subpopulations. However, not all significant sites are listed on the register, and on-going liaison will be maintained with local Aboriginal community representatives to ensure appropriate input to proposed recovery actions.

7. Social and economic interests

The implementation of this recovery plan is not expected to have any negative social or economic impacts. Widespread land clearing has been regulated by government policy in WA since the early 1980s. Positive impacts are predicted for tourism particularly as the numbat is an iconic species and a drawcard to places where they are easily seen.

8. Broader biodiversity benefits

Habitat protection and management for numbat recovery provides broader biodiversity benefits for many other species, including a number of threatened species. Benefits to other threatened or priority medium-sized mammal species are associated with regular fox and feral cat control (e.g. woylie, (*Bettongia penicillata ogilbyi*), chuditch (*Dasyurus geoffroii*), western ringtail possum (*Pseudocheirus occidentalis*), western brush wallaby (*Macropus irma*), tammar wallaby (*Macropus eugenii*), brush-tailed phascogale (*phascogale tapoatafaa*), southern brown bandicoots (*Isoodon obesulus fusciventer*)) and ground-nesting birds (e.g. Australian bustard (*Ardeotis australis*), bush stone-curlew (*Burhinus grallarius*), malleefowl (*Leiopoa ocellata*)).

A number of Declared Rare Flora occur within numbat habitat and are likely to benefit from habitat protection and management (e.g. *Grevillea involucrata*, *Banksia aurantia* and *Thomasia montana)*.

The recovery actions put in place for the numbat may potentially be of benefit to the following ecological communities:

- Montane mallee of the Stirling Range. (Priority 1)
- Proteaceae dominated kwongkan shrublands of the southeast coastal floristic province. (TEC, EPBC Act)

The numbat is the only mammal species in Australia that feeds solely on termites. Digging out hollow logs, trunks and branches by numbats creates hollows for smaller animals, such as small dasyurids, passerine birds, skinks and geckos, and digging in the soil improves water penetration and seed germination. The species is therefore likely to play a vital ecological role in maintaining broad ecological functioning within these communities.

9. Existing conservation measures

This is the second recovery plan prepared for the numbat. The first was prepared in 1994 (Friend 1994). A recovery team was established in 1993 and has assisted in the development of both recovery plans. Significant progress has been made on the recovery actions identified in the first recovery plan and a summary of these are presented below.

9.1 Management of existing subpopulations

Predator control

An ongoing fox control program is an essential part of any in-situ numbat conservation project. At the beginning of 1989, the area of Dryandra Woodland subject to fox control was extended from 2000 ha to over 15000 ha and the baiting program was taken over from research personnel by local operational staff as part of the management of Dryandra. The numbat sighting rate on standard vehicle surveys increased from 0.14 per 100 km in 1979 to 11.75 per 100 km in 1992, although it fell to 5.5 per 100 km in 1993, and since then has remained below that level. Similarly since 1989 extensive fox baiting was undertaken in the Upper Warren area. The implementation of the Western Shield wildlife recovery program over most conservation land in the southwest has been of great benefit to the protection of the *in-situ* numbat subpopulations. This program is now responsible for fox control on both of the original numbat subpopulations (Dryandra and Upper Warren) and all numbat reintroduction sites in the south-west (Boyagin, Tutanning, Batalling, Dragon Rocks, Stirling Range NP and Cocanarup Timber Reserve, as well as the unsuccessful Mt Dale reintroduction site). As part of the Western Shield program feral cat baiting is being incorporated into some sites using Eradicat®.

Yookamurra and Scotia (AWC) as well as Roxby Downs (Arid Recovery) Sanctuaries are fenced to exclude foxes and feral cats, as well as rabbits.

Population monitoring

Annual monitoring of the numbat subpopulation at Dryandra, by driven survey, has been carried out by research personnel since 1981. A standard circuit has been used since 1987 to allow a comparison of sighting rates between years. The Upper Warren subpopulation was surveyed by similar methods for the first time in 1993, although data from incidental sightings in the area are available for the period 1972-1981 (Christensen *et al.* 1984). Due to the greater density of the understorey, sighting rates in jarrah forest at Upper Warren are lower than in wandoo woodland at Dryandra. Monitoring is

also carried out at reintroduction sites. Driven surveys have been carried out at Boyagin since 1992. Searches for diggings have been used at Boyagin in parallel with driven surveys and the results show similar trends (Friend 1990).

Driven survey is also used to assess numbat numbers at Yookamurra and Scotia (Viera *et al.* 2004; M. Hayward pers. comm.). Track counts are also used at Scotia up until 2012 (J. Cathcart, pers. comm.).

Habitat management research and implementation

Management of natural vegetation in Dryandra Woodland has been formulated to benefit nature conservation. Certain regulations are currently enforced in addition to those that apply in all State forest. Dogs are not allowed, and firewood collection is restricted to areas allocated for this purpose in the recently thinned mallet plantations. The current management plan for Dryandra Woodland, covering 10 bush blocks near Dryandra settlement and seven blocks 20 km away near Highbury, was published in 2011 (DEC 2011). The plan proposes that 16 337 ha near Dryandra settlement, currently reserved as State forest, be converted to National Park. In the interim, this land is being managed as if it already has this status. If the proposed declaration as National Park is implemented, appropriate regulations will come into force in these areas.

Prescribed burning in areas of natural vegetation at Dryandra is restricted to strategic buffer strips 50-100 metres wide, and areas immediately adjoining the Settlement and recreation sites. A similar strategy is in place at Boyagin, while at Tutanning, where a dense network of tracks exists, fire is introduced occasionally into strategically located blocks to prevent the accumulation of heavy fuel loads. The use of fire to regenerate senescent *Gastrolobium* thickets is foreshadowed in the Dryandra management plan, and a burn program to regenerate kwongan patches and reduce *Allocasuarina* invasion has been undertaken at Tutanning.

In the Upper Warren, regular prescribed burning of forest areas recognises the importance of the area for threatened fauna and forest management practices in State Forest areas such as timber harvesting, firewood gathering and flora harvesting and these are managed in accordance with the Forest Management Plan 2014-2023 (Conservation Commission 2013). The Perup Management Plan provides direction for habitat management for conservation areas in the Upper Warren.

Habitat management in other wheatbelt nature reserves, such as Dragon Rocks, involves reducing the likelihood of a single bushfire burning a significant portion of the reserve and reintroducing a fire mosaic. In the Stirling Range NP, the use of prescribed fire is important in reducing bushfire risk and for protection of surrounding properties.

At Yookamurra and Scotia, habitat management is aimed at promoting biodiversity. In these semi-arid environments, fuel loads are low and there is a low risk of a devastating bushfire.

9.2 Genetic survey of existing subpopulations

A mtDNA study of remnant numbat subpopulations in the south-west of WA (Fumagalli *et al.* 1999) showed that more genetic variation had been retained at Dryandra than at Upper Warren. There have been no studies of reintroduced subpopulations.

9.3 Translocation

In 1985, a reintroduction of numbats into Boyagin Nature Reserve commenced in conjunction with regular fox control; this subpopulation still persists there today. A program of fox control and numbat translocation has resulted in the establishment of five further reintroduced subpopulations in Western Australia (Table 1). Action by Earth Sanctuaries Limited and now by the Australian Wildlife Conservancy has resulted in the establishment of two additional subpopulations in fenced sanctuaries in South Australia and New South Wales. Of the 12 translocated subpopulations six are currently considered self-sustaining (Table 1).

Reintroduction protocol

A reintroduction protocol has been developed. The protocol in a large area is to release 15-20 numbats (comprising 50% females, 25% first-year males and 25% 2+ year-old males) into the area in November/December each year for three successive years. Translocation during these months mimics the natural dispersal of young, and also utilises the only time of year when females do not have dependent young. All animals are radio-collared before release. In January, when they have established new home ranges, the numbats are located by use of a light aircraft fitted with radio-tracking equipment. Soft-release enclosures are not used, due to the difficulty of providing sufficient food within the enclosures to support the translocated animals for the necessary time. Numbats dispersing to areas remote from others can be moved back to the release area in April-June, when they are less likely to disperse again. Young born to radio-collared females at the reintroduction site are captured before dispersal and also fitted with radio-collars. The young numbats are also located in January by use of the aircraft. Monitoring by checking for survival at least monthly is continued as long as collars can be maintained on the animals. Estimates of mortality rate can be made using this data, to allow predictions about the fate of the subpopulation using population viability analysis. Subsequent monitoring is carried out by systematic searches for signs (diggings, scats) and driven surveys (if track access is sufficient). Five years after the third release year, an assessment may be made of the success of the translocation.

9.4 Health monitoring

Knowledge of the health status of numbats has come mainly though veterinary attention in captivity and a study which examined a number of health parameters in the wild subpopulation at Dryandra (Haigh 1994). The importance of pathogens such as *Mycobacterium* (Gaynor *et al*. 1990) and erysipelas (Vaughan-Higgins *et al*. 2013) recorded in isolated cases has not been established.

9.5 Captive breeding

Numbats were bred and raised to adulthood for the first time at the Western Australian Wildlife Research Centre, Woodvale in 1984-6, during a project funded by World Wildlife Fund for Nature Australia and run by the Department of Fisheries and Wildlife, then later Department of Conservation and Land Management. An artificial diet, based on egg and low lactose milk powder supplemented with termites, was developed during that project. Since 1986, the captive colony has been housed at Perth Zoo, with transfers of animals in 1989, 1990 and 1992 to Woodvale for breeding. Numbats bred at Woodvale in 1985, 1989, and 1990 (Friend and Whitford 1993). The first breeding at Perth Zoo was

achieved in 1993. To date 176 captive born numbats have been released. Comprehensive husbandry protocols have been developed by the zoo (Power and Monaghan 2004) and the colony has been used to facilitate numerous research projects.

After the dramatic decline of the Dryandra numbat subpopulation in 1993, the population could no longer sustain the removal of 20-30 individuals each year for the wild-wild translocations carried out since 1985. Since 1994 the breeding colony at Perth Zoo has been the primary source of reintroduction stock. Regular incorporation of wild animals into the captive colony is required to maintain its genetic viability. The captive colony is also used to provide animals for display and public education at Perth Zoo.

9.6 Public Awareness

Project Numbat is a Perth-based community action group that established in 2005. Their objectives are to raise public awareness of the numbat and the recovery program, carry out fund raising to support numbat recovery and provide volunteer assistance and on-ground action. Project Numbat has produced an education package on numbat recovery for use in schools. Members visit schools and take numbat displays and merchandise to shopping centres and events. Their education and fundraising efforts have been significant.

Perth Zoo has effectively contributed to education and increased public awareness of numbats through its numbat display at the zoo and education programs. Australian Wildlife Conservancy also increased awareness through their programs at Scotia Sanctuary.

The Department of Parks and Wildlife have a number of visitor centres, interpretive signage and education programs in various locations that promote the plight of the numbat, including Barna Mia visitor experience at Dryandra Woodland and Perup nature guest house in Tone Perup Nature Reserve. In addition, the Western Shield program has a dedicated community awareness and education program and the numbat is a prominent species in that program.

9.7 Numbat Recovery Team

The Numbat Recovery Team was appointed in July 1993, to oversee the production of the first Recovery Plan and to coordinate the research and management of the numbat as outlined in it. The team now comprises representatives from the Department of Parks and Wildlife, Perth Zoo, Australian Wildlife Conservancy, Arid Recovery, the South Australian Department of Environment, Water and Natural Resources, the New South Wales Office of Environment and Heritage and the Project Numbat community action group. Other organisations that become involved with the program in the future may be invited to join the Recovery Team.

The Numbat Recovery Team reports annually to the Department of Parks and Wildlife's Science and Conservation Division and to funding agencies as required.

10. Management practices and policies

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

- Dryandra Woodland Management Plan No. 70, 2011 (DEC 2011)
- Perup Management Plan No. 72, 2012 (DEC 2012a)
- Stirling Range and Porongurup National Parks Management Plan 1999-2009 (CALM 1999)
- Western Shield Fauna Recovery Program: Interim Strategic Plan 2009/10 – 2012/13 (DEC 2008)
- Western Shield – Bringing Back our Wildlife (Burbidge *et al.* 1985)
- Policy Statement No. 3 Management of *Phytophthora* disease (DPaW 2014)
- Policy Statement No. 29 Translocation of threatened flora and fauna (CALM 1995)
- Policy Statement No. 33 Conservation of endangered and specially protected fauna in the wild (CALM 1991)
- Guidelines for Protection of the Values of Informal Reserves and Fauna Habitat Zones, Department of Environment and Conservation, Sustainable Forest Management Series, SFM Guideline No. 4 (DEC 2009g)
- Guidelines for the Selection of Fauna Habitat Zones, Department of Environment and Conservation, Sustainable Forest Management Series, SFM Guideline No. 6. (DEC 2010b)
- Forest Management Plan 2014-2023 (Conservation Commission of WA 2013)
- Strategic Plan for Biodiversity Conservation Research (DEC 2007)
- South Coast Regional Fire Management Plan 2009-2014 (2009f)
- South Coast Threatened Species and Ecological Communities Strategic Management Plan (Gilfillan *et al*. 2009)
- Fitzgerald Biosphere Recovery Plan (DEC 2012b)
- Nature Conservation Service Regional Plans for the South Coast Region, South West Region, Swan Region, Warren Region and Wheatbelt Region (DEC 2009a, DEC 2009b, DEC 2009c, DEC 2009d, DEC 2009e)
- Threat abatement plan for disease in natural ecosystems caused by *Phytophthora cinnamomi* (Department of the Environment 2014)
- Threat abatement plan for predation by European red fox (DEWHA 2008)
- Threat abatement plan for predation by feral cats (Commonwealth of Australia 2015)
- Survey guidelines for Australia's threatened mammals. (DSEWPaC 2011)

To minimise the risk of bushfire to numbats, management practices such as prescribed burning, firebreaks, and back-burning, may be required. Department of Parks and Wildlife addresses this in WA through the Incident Management System and the 'Master Burn Plan' and sets annual priorities for areas to be burnt prescriptively to reduce fuel loading in an effort to reduce the intensity and frequency of bushfires. 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.

11. Guide for decision makers

Details of current threats to numbats are presented in section 3 and these should be carefully considered by decision makers.

Developments in the immediate vicinity of the population or within the habitat that is defined as critical to survival should be carefully assessed.

Any proposed on-ground works (clearing, firebreaks, road works, burning, drainage, mining etc.) in the immediate vicinity of numbat subpopulations should demonstrate that they will not have an impact on the species, or on its habitat or potential habitat.

Actions that remove native vegetation (including logs and debris) such as increased fire frequency, vegetation clearing, mining and forestry can result in a significant impact on the numbat, particularly if these actions remove habitat critical for survival or occur within the vicinity of habitat critical to survival.

12. Recovery

12.1 Recovery goals and objectives

The long term goal of the recovery program for the numbat is to improve its conservation status by increasing the number of subpopulations and the size of subpopulations.

This recovery plan guides the recovery of the numbat for the next 10 years. The objectives are to:

1. Ensure the security of existing self-sustaining subpopulations.
2. Extend the current distribution of the numbat.
3. Ensure genetic health and diversity is maintained.
4. Increase community awareness and participation in the conservation of the numbat.

Criteria for success:

This recovery plan will be deemed successful if, within a 10 year period, all of the following are achieved:

- All subpopulations currently assessed as self-sustaining persist.
- Additional subpopulations have been established at one or more sites.
- Genetic health and diversity is described and maintained.
- Increased recognition of the status of the numbat and support towards its conservation.

Criteria for failure:

This recovery plan will be deemed unsuccessful if, within a 10 year period, any of the following occur:

- Any of the subpopulations currently assessed as self-sustaining are lost.
- No additional subpopulations have been established.
- No increased recognition of the status of the numbat or support towards its conservation.

12.2 Recovery Actions

There are recovery actions identified to achieve each of the recovery objectives. Recovery actions are assigned a priority ranking:

- Priority 1: Taking prompt action is necessary in order to mitigate the threats and ensure the persistence of the species.
- Priority 2: Action is necessary to mitigate threats and work towards the long-term recovery of the species.
- Priority 3: Action is desirable, but not critical to recovery at this point in time but will provide for longer term maintenance of recovery.

Objective 1: Ensure the security of existing self-sustaining subpopulations.

The security of existing self-sustaining subpopulations (see table 1) requires the continuation or improvement of introduced predator and habitat management at these sites.

Fox control is necessary in all unfenced areas and outside those fenced areas supporting numbat subpopulations to enhance the security of the species. Currently all sites in WA where self-sustaining subpopulations exist are baited under the Department of Parks and Wildlife's Western Shield program. There is strong evidence that mesopredator release of feral cats occurs under fox control regimes and that feral cats are a significant threat to numbats. However, no experiments have been carried out to measure the effect of removing feral cats on a numbat subpopulation. The effectiveness and practicality of all methods to control feral cats need to be investigated and an effective integrated predator control program developed and implemented at all numbat subpopulation sites.

Although fire is an element of the natural environment of the numbat, fire may negatively impact numbats by directly killing them or exposing them to increased predator risk due to decreased cover. Further investigation is required to understand the short and long-term impacts of fire on numbat survival and their habitat. The effects of prescribed burns on numbat movement and survival, changes in hollow availability and termite activity has been studied in wandoo woodland at Dryandra but similar studies need to be carried out in jarrah forest sites.

Numbats occur in areas of State forest subject to selective timber harvesting and persist in areas that were logged historically. One study showed that the effect of selective timber harvesting on resident numbats was minimal and limited to disturbance only during the actual operation. Further work is needed to inform and develop silviculture guidelines for numbat subpopulation areas.

In order to determine the effectiveness of site management strategies, and to provide warning of any declines, monitoring of all known subpopulations is required. Current techniques include driven surveys, distance sampling and digging surveys but each has its limitations especially when numbat numbers are low. Other methods such as camera deployment or quantitative digging surveys need to be investigated to develop a more robust method of estimating numbat numbers.

Action	Description	Priority	Performance Criteria	Responsibility
1.1	Continue and improve the effectiveness of fox control at existing numbat subpopulation sites.	1	Effective fox baiting is maintained at each WA subpopulation site (Table 1). Fenced sites (Yookamurra, Scotia, Perup Sanctuary) remain free from introduced predators.	DPaW, AWC
1.2	Identify and implement where practical appropriate methods of feral cat control at existing numbat subpopulation sites.	1	Effective feral cat control methods are identified and implemented at each WA subpopulation site (Table 1). Fenced sites (Yookamurra, Scotia, Perup Sanctuary) remain free from introduced predators.	DPaW, AWC.
1.3	Manage fire in numbat habitat to enhance numbat survival.	1	The presence of numbats is considered during the planning of prescribed burns, and management of bushfires.	DPaW
1.4	Investigate the effect of prescribed fire on numbats and aspects of their habitat in jarrah forest.	2	The short and long-term effect of prescribed fire on numbats and their habitat is determined. Guidelines to enhance numbat survival in relation to prescribed burns is developed and utilised during prescribe burn planning.	DPaW
1.5	Develop silviculture guidelines for numbat habitat.	2	The short and long-term effect of timber harvesting on numbats and their habitat is determined. Guidelines to enhance numbat survival and persistence in relation to silviculture are developed and utilised.	DPaW
1.6	Develop a robust method of estimating numbers to monitor subpopulation trends.	1	Accurate subpopulation estimates and trends can be determined.	DPaW, researchers

1.7	Maintain current monitoring methods until 1.6 complete, then incorporate new methods into monitoring program.	1	Current methods of monitoring numbats are maintained until more robust methods of subpopulation estimation are available. Incorporate new methods into monitoring program.	DPaW, researchers
1.8	Monitor the effectiveness of fox and feral cat control programs in reducing activity and/or abundance of these predators and the responses of numbat subpopulations.	1	A monitoring program is designed and implemented to measure the effectiveness of predator control programs at each WA subpopulation site. The monitoring program measures both introduced predators and numbat subpopulations.	DPaW, AWC, Project Numbat
1.9	Monitor health of individuals in all subpopulations.	3	Protocols developed to determine health status and pathogen presence. Health monitoring protocols are implemented whenever animals are captured.	DPaW, researchers
1.10	Proposed land tenure change of 16 337 ha of State forest in Dryandra to national park implemented.	2	Land tenure of proposed area of Dryandra State forest changed to National Park.	DPaW

Objective 2: Extend the current distribution of the numbat.

The security and conservation status of the numbat will be enhanced by the establishment of additional subpopulations to extend the current distribution of numbats. Inclusion of habitats from which numbats have become extinct will allow evolutionary processes to continue across a broader part of the species' former range. The development of a translocation plan for the species will include an evaluation of where to source animals (i.e. either captive breeding programs or from existing *in situ* subpopulations), consider the impact on source subpopulations, the selection of reintroduction sites, and strategies to maintain genetic diversity (also see objective 3). Decisions regarding the source of animals for translocations as well as captive breeding should take into account the genetics of the available subpopulations once more detailed genetic information is available.

While 'wild' individuals are preferred as a source for translocations it is acknowledged that currently there are no subpopulations in WA that could support removal of appropriate numbers required for translocation, or the logistics of capturing a sufficient number are impractical. Perth Zoo hosts the only numbat captive breeding colony and currently supplies the majority of animals for translocations. Integral in the genetic management of this colony is the regular incorporation of a small number of individuals captured by the Department of Parks and Wildlife from wild subpopulations.

Action	Description	Priority	Performance Criteria	Responsibility
2.1	Develop a translocation plan for the numbat including: • review and update of current protocols • protocols for assessing suitability for sourcing animals, • identification and prioritisation of release sites, • protocols for monitoring source/translocated subpopulations, • strategies to maintain or improve genetic diversity in all subpopulations (also see recovery objective 3).	1	Translocation plan developed for the numbat.	DPaW, Perth Zoo
2.2	Carry out reintroduction of numbats to at least two sites, if possible including habitat types in which subpopulations do not currently exist.	1	Two additional self-sustaining subpopulations of numbats are established.	DPaW, AWC, Perth Zoo
2.3	Continue and improve effective predator and habitat management at new and recent translocation sites.	1	Effective predator control and habitat management is implemented at new and recent translocation sites.	DPaW, AWC
2.4	Maintain the captive breeding colony at Perth Zoo until at least two new populations are established.	1	Captive breeding colony is maintained at Perth Zoo.	Perth Zoo, DPaW

Objective 3: Ensure genetic health and diversity is maintained.

A study of the genetic variability within and between subpopulations is needed to understand the health of the overall population and subpopulations. Such information should underpin decisions regarding where to source animals for translocations and captive breeding, optimum number of animals needed to establish new subpopulations and if there is a need to supplement existing subpopulations.

Action	Description	Priority	Performance Criteria	Responsibility
3.1	Determine the genetic variably within and between all self-sustaining subpopulations.	2	Genetic variation within and between subpopulations determined.	DPaW, Researchers
3.2	Develop and implement strategies to maintain or improve genetic variability within subpopulations.	2	Strategies to maintain or improve genetic diversity implemented.	DPaW

Objective 4: Increase community awareness and participation in the conservation of the numbat.

The recovery of the numbat is dependent on a relatively large number of reintroductions, and the difficulty of monitoring requires a high commitment of funds and personnel. Public support is essential to maintain the funding necessary to complete these actions, and assistance from interested members of the public can be utilised in some of the management and monitoring actions. The numbat is a very high profile species, and has attracted much public interest, particularly in Western Australia, where it is the State's mammal emblem. This should at least be maintained.

Programs to increase community awareness of the numbat, its plight and recovery actions are currently being undertaken by Department of Parks and Wildlife, Perth Zoo, AWC and the community group, Project Numbat. Project Numbat is particularly active in encouraging community participation in numbat recovery through membership, fundraising, volunteer assistance in the field, and is active in implementing and delivering school education programs regarding the numbat.

Action	Description	Priority	Performance Criteria	Responsibility
4.1	Support the Project Numbat community action group in Western Australia.	1	Project Numbat profile and level of support increases.	DPaW, Perth Zoo
4.2	Formulate and implement an education strategy to increase public awareness of the numbat including Parks and Wildlife visitor centres and programs (e.g. Barna Mia, Western Shield), AWC and Perth Zoo interpretation programs and Project Numbat education programs.	2	Increased awareness of numbats is observed.	Project Numbat, DPaW, Perth Zoo, AWC
4.3	Seek grants and sponsorships to support numbat recovery.	1	Funding to achieve priority numbat recovery actions is increased.	All

13. Implementation

This Recovery Plan guides the recovery actions for the numbat over the next 10 years. The plan will be implemented and managed by Department of Parks and Wildlife, with the support of other stakeholders, most likely through a Recovery Team. Technical, scientific, habitat management or education components of the Recovery Plan may be referred to specialist groups as required. The plan will run for 10 years from the date of its adoption, or until replaced, but will remain in force until withdrawn or replaced. The Recovery Plan will be reviewed by Department of Parks and Wildlife, in consultation with the Recovery Team within five years of the date of its adoption, or sooner if necessary. Any changes to management or recovery actions will be documented accordingly.

The estimated cost of implementing this recovery plan for the first five years is presented in Table 2. 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. Cost per year has been rounded to the nearest thousand dollars. Note that estimated costs do not account for inflation and do not include recurrent management activities undertaken on conservation estate.

Table 2. Estimated cost ($000's) of implementing the Recovery Plan over the first five years.

	Recovery Action	Y1	Y2	Y3	Y4	Y5	Total
1.1	Continue and improve the effectiveness of fox control at existing numbat subpopulation sites.	250	250	250	250	250	1250
1.2	Identify and implement appropriate methods of feral cat control at existing numbat subpopulation sites.	50	100	150	200	250	750
1.3	Manage prescribed fire in numbat habitat to enhance numbat survival.	10	10	10	10	10	50
1.4	Investigate the effect of prescribed fire on numbats and aspects of their habitat in jarrah forest.		15	15	15		45
1.5	Develop silviculture guidelines for numbat habitat.		5				5
1.6	Develop methods to estimate numbers/monitor trends.	25	25				50
1.7	Undertake monitoring using the accepted methods.	30	30	40	40	40	180
1.8	Monitor effectiveness of fox and feral cat control programs and the responses of numbat subpopulations.	25	25	25	25	25	125
1.9	Monitor health of individuals in all subpopulations.	10	10	10	10	10	50
1.10	Land tenure of proposed area of Dryandra State forest to national park.	*	*	*	*	*	*
2.1	Develop a translocation plan for the numbat.	10	10				20
2.2	Carry out reintroduction of numbats to at least two sites.		40	20	40	20	120
2.3	Continue and improve effective predator and habitat management at new and recent translocation sites.	*	*	*	*	*	*
2.4	Maintain the captive breeding colony at Perth Zoo.	200	200	200	200	200	1000
3.1	Determine genetic variably within and between subpopulations.	10	50				60
3.2	Develop and implement strategies to maintain or improve genetic variability within subpopulations.			20	20	20	60
4.1	Support the Project Numbat community action group.	5	5	5	5	5	25
4.2	Formulate and implement an education strategy to increase public awareness of the numbat.		10	5	5	5	25
4.3	Seek grants/sponsorships to support numbat recovery	2	2	2	2	2	10
	TOTAL	627	787	752	822	837	3825

* indicates unable to estimate costs accurately

14. References

Algar, D. and Mitchell, S. (2013). Controlling cats: the work continues. *Landscope* 28(3): 54-58.

Anon. (1949) Save our native fauna - No. 1. *Public Service Journal of Victoria* (April-May 1949) 39: iv.

Barrett, S., Comer, S., McQuoid, N., Porter, M., Tiller, C. and Utber, D. (2009). Identification and Conservation of Fire Sensitive Ecosystems and Species of the South Coast Natural Resources Management Region. WA Department of Environment and Conservation, South Coast Region, Albany, WA.

Bester, A.J. and Rusten, K. (2009). Trial translocation of the numbat (*Myrmecobius fasciatus*) into arid Australia. *Australian Mammalogy* 31, 9–16

Burbidge, A.A. andMcKenzie, N.L. (1989). Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. *Biological Conservation* 50:143–98.

Burbidge, A.A., Johnson, K.A., Fuller, P.J. and Southgate, R.I. (1988). Aboriginal knowledge of the mammals of the central deserts of Australia. *Australian Wildlife Research* 15 : 9-39.

Burbidge, A.A., Start, A.N., Morris, K.D. and Armstrong, R. (1985). Western Shield – Bringing Back our Wildlife. Department of Conservation and Land Management, Perth.

Burrows, N.D., McCaw, W.L. and Maisey, K.G. (1987). Planning for fire management in Dryandra Forest. In *Nature Conservation: the role of remnants of native vegetation.* (eds. D.A. Saunders, G.W. Arnold, A.A. Burbidge and A.J.M. Hopkins), pp. 305-12. Surrey Beatty & Sons, Sydney.

Calaby, J. H. (1960). Observations on the Banded ant-eater *Myrmecobius fasciatus* Waterhouse (Marsupialia). *Journal of Zoology (Lond.)*, 135(2): 183–207.

CALM (1991). Policy Statement No. 33: Conservation of endangered and specially protected fauna in the wild. WA Department of Conservation and Land Management, Perth, WA.

CALM (1995). Policy Statement No. 29: Translocation of threatened flora and fauna. WA Department of Conservation and Land Management, Perth, WA.

CALM (1999) Stirling Range and Porongurup National Parks Management Plan No. 42 1999-2009. WA Department of Conservation and Land Management, Perth, WA.

Caughley, G. and Gunn, A. (1996). Conservation Biology in Theory and Practice. Blackwell Science, Carlton.

Christensen, P., Maisey, K. and Perry, D.H. (1984). Radio-tracking the numbat, *Myrmecobius fasciatus*, in the Perup Forest of Western Australia. *Australian Wildlife Research* 11: 275-288.

Christensen, P.E.S. (1980). A sad day for native fauna. *Forest Focus,* 23: 3-12.

Christensen, P.E.S. and Burrows, N. (1994). Project Desert Dreaming: the reintroduction of mammals to the Gibson Desert. Reintroduction and the numbat recovery program. In *Reintroduction Biology of Australian and New Zealand Fauna* (ed. M. Serena), pp. 199–208. Surrey Beatty & Sons, Chipping Norton.

Commonwealth of Australia (2015). Threat abatement plan for predation by feral cats. Commonwealth of Australia, Canberra.

Connell, G.W. and Friend, J.A. (1985). Searching for numbats. *Landscope* 1(2): 21-26.

Conservation Commission of WA (2013). *Forest Management Plan 2014 – 2023*. Conservation Commission of WA, Perth.

Cooper, C. E., and Withers, P. C. (2004). Termite digestion by the numbat (*Myrmecobius fasciatus*): the inter-relationship between diet, digestibility, and energy and water turnover for myrmecophages. *Physiological and Biochemical Zoology* 77: 641–650.

Dale, R. (1833). Letters from Mr Dale, giving a summary description of the country passed over in going to Mount Bakewell, and, also, in an expedition to examine the country to the north and south of that place. In *Journals of Several Expeditions Made in Western Australia During the Years 1830, 1831, and 1832; under the sanction of the Governor, Sir James Stirling, containing the latest authentic information relative to that country, accompanied by a map.* (ed. J. Cross), pp. 155-160. J. Cross, London.

Department of Environment and Conservation (DEC) (2007). A Strategic Plan for Biodiversity Conservation Research 2008-2017. WA Department of Environment and Conservation, Science Division, Perth.

Department of Environment and Conservation (DEC) (2008). Western Shield Fauna Recovery Program: Interim Strategic Plan 2009/10 – 2012/13. WA Department of Environment and Conservation, Perth.

Department of Environment and Conservation (DEC) (2009a) Nature Conservation Service South Coast Region Plan 2009-2014. WA Department of Environment and Conservation [unpublished report]

Department of Environment and Conservation (DEC) (2009b) Nature Conservation Service South West Region Plan 2009-2014. WA Department of Environment and Conservation [unpublished report]

Department of Environment and Conservation (DEC) (2009c) Nature Conservation Service Swan Region Plan 2009-2014. WA Department of Environment and Conservation [unpublished report]

Department of Environment and Conservation (DEC) (2009d) Nature Conservation Service Warren Region Plan 2009-2014. WA Department of Environment and Conservation [unpublished report]

Department of Environment and Conservation (DEC) (2009e) Nature Conservation Service Wheatbelt Region Plan 2009-2014. WA Department of Environment and Conservation [unpublished report]

Department of Environment and Conservation (DEC) (2009f). South Coast Regional Fire Management Plan 2009- 2014. WA Department of Environment and Conservation, Perth [unpublished report].

Department of Environment and Conservation (DEC) (2009g). Guidelines for Protection of the Values of Informal Reserves and Fauna Habitat Zones, Department of Environment and Conservation, Sustainable Forest Management Series, SFM Guideline No. 4

Department of Environment and Conservation (DEC) (2010). Review of Numbat Conservation, (Ed. G. Wyre). WA Department of Environment and Conservation, Perth.

Department of Environment and Conservation (DEC) (2011). Dryandra Woodland Management Plan No. 70 2011. WA Department of Environment and Conservation, Perth and Conservation Commission of Western Australia, Perth.

Department of Environment and Conservation (DEC) (2012a). Perup Management Plan No. 72 2012. WA Department of Environment and Conservation, Perth and Conservation Commission of Western Australia, Perth.

Department of Environment and Conservation (DEC) (2012b). Fitzgerald Biosphere Recovery Plan: A Landscape Approach to Threatened Species and Ecological Communities Recovery and Biodiversity Conservation.WA Department of Environment and Conservation, Albany.

Department of Environment, Water, Heritage and the Arts (DEWHA) (2008). Threat abatement plan for predation by European red fox. Department of Environment, Water, Heritage and the Arts, Canberra.

Department of Parks and Wildlife (2014). Policy Statement 3. Management of *Phytophthora* disease. Department of Parks and Wildlife, Perth.

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (2011) Survey guidelines for Australia's threatened mammals. Commonwealth Government of Australia, Canberra.

Department of the Environment (2014). *Threat abatement plan for disease in natural ecosystems caused by Phytophthora cinnamomi*. Commonwealth Government of Australia, Canberra.

Department of the Environment (2014). Recovery Planning Compliance Checklist for Legislative and Process Requirements. Commonwealth Government of Australia, Canberra. <http://www.environment.gov.au/resource/recovery-planning-compliance-checklist-legislative-and-process-requirements-be-provided> (accessed January 2015).

Finlayson, H. H. (1933). On mammals of the Lake Eyre Basin. I. The Dasyuridae. *Transactions of the Royal Society of South Australia* 57:195-202.

Finlayson, H.H. (1961). On central Australian mammals. Part IV. The distribution and status of central Australian species. *Records of the South Australian Museum* 14: 141-191.

Friend, J. A. and Thomas, N.D. (2003). Conservation of the numbat (*Myrmecobius fasciatus*). In *Predators With Pouches: the Biology of Carnivorous Marsupials* (eds. M. Jones, C. Dickman and M. Archer) pp. 452–463. CSIRO, Collingwood.

Friend, J.A. and Whitford, D. (1993). Maintenance and breeding of the numbat (*Myrmecobius fasciatus*) in captivity. In *The Biology and Management of Australian Marsupials* (eds. M. Roberts, J. Carnio, G. Crawshaw, & M. Hutchins), pp. 103–24. Metropolitan Toronto Zoo and the Monotreme and Marsupial Advisory Group of the American Association of Zoological Parks and Aquariums, Toronto.

Friend, J.A. (1985). Diet and seasonal patterns of activity in the numbat (*Myrmecobius fasciatus*). *Australian Mammal Society Bulletin* 9: 47.

Friend, J.A. (1989). Myrmecobiidae. In *Fauna of Australia: Volume IB. Mammalia*. (eds. D.W. Walton and B.J. Richardson), pp.583-590. Australian Government Publishing Service, Canberra.

Friend, J.A. (1990). The numbat *Myrmecobius fasciatus* (Myrmecobiidae): history of decline and potential for recovery. *Proceedings of the Ecological Society of Australia 1990*, 16: 369-377.

Friend, J.A. (1994) Recovery Plan for the Numbat (*Myrmecobius fasciatus*) 1995-2004. Western Australian Wildlife Management Program No. 18.

Friend, J.A. (2008). Numbat *Myrmecobius fasciatus*. In *The Mammals of Australia 3rd Edition, (eds.* S. van Dyck and R. Strahan), pp.163-5. Reed New Holland, Sydney

Friend, J.A. (2012). TS63 Dryandra numbat recovery. Project Report 2011/12. Specific Nature Conservation Projects Program. WA Department of Environment and Conservation.

Friend, J.A. and Burrows, R.G (1983). Bringing up young numbats. *SWANS* 13(1): 3-9.

Friend, J.A. and Thomas, N.D. (1994). Reintroduction and the numbat recovery program. In *Reintroduction biology of Australian and New Zealand Fauna,* (ed. M. Serena), pp. 189-98. Surrey Beatty & Sons, Chipping Norton.

Friend, J.A. and Whitford, D. (1988). Captive breeding of the numbat, *Myrmecobius fasciatus*. Unpublished report to World Wildlife Fund Australia.

Friend, J.A., Fuller, P.J. and Davis, J.A. (1982). The numbat in central Australia. *SWANS*, 12(3): 21-26.

Friend, T. and Burbidge, A. (2008). *Myrmecobius fasciatus*. In: *IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2*. <www.iucnredlist.org>. Downloaded on 23 January 2012.

Friend, T. (1996). Studies on reproduction in the numbat *Myrmecobius fasciatus. Newsletter of the Australian Mammal Society* November 1996: 12.

Fumagalli, L., Moritz, C., Taberlet, P. and Friend, J.A. (1999). Mitochondrial DNA sequence variation within the remnant populations of the endangered numbat (Marsupialia: Myrmecobiidae: *Myrmecobius fasciatus*). *Molecular Ecology,* 8: 1545–9.

Gaynor, W.T., Cousins, D.V. and Friend, J.A. (1990). Mycobacterial infection in numbats (*Myrmecobius fasciatus*). *Journal of Zoo and Wildlife Medicine* 21(4): 476-479.

Gilfillan, S., Mitchell, P., Newell, J., Danks, A. and Comer, S. (2009). South Coast Threatened Species and Eoclogical Communities Strategic Management Plan. WA Department of Environment and Conservation, Albany.

Gill (1872). Arrangement of the families of mammals with analytical tables. *Smithsonian Miscellaneous Collections,* 11: i–vi, 1–98.

Glauert, L. (1935). Answers to correspondence. *Our Rural Magazine* June 1935: 147-150.

Griffiths, M. (1968). Echidnas. Pergamon Press, London, United Kingdom.

Groom, C. (2010). Justification for continued conservation efforts following the delisting of a threatened species: a case study of the woylie, *Bettongia penicillata ogilbyi* (Marsupialia: Potoroidae). *Wildlife Research*, 37: 183-193.

Haigh, S.A. (1994). An investigation of the health status and occurrence of disease agents in several threatened Western Australian mammal species. Unpublished report to the Department of Conservation and Land Management, Perth, Western Australia.

Haigh, S.A. and Friend, J.A. (1999). Veterinary aspects of several threatened Western Australian mammal species. *Australian Association of Veterinary Conservation Biologists Newsletter* 16: 5-6.

IOCI (2010). Update on IOCI Research: WA rainfall – what the past can tell us, and what the future may hold. Factsheet 4, Indian Ocean Climate Initiative, Perth

IUCN (2013). IUCN Red List of Threatened Species. Version 2013.2. Available at: www.iucnredlist.org. Accessed February 2014.

Jones, A.D. (1954). The recent increase of the rarer native mammals. VII. Manjimup. *West Australian* Naturalist 4: 139-40.

Kinnear, J. E., Onus, M. L. and Sumner, N. R. (1998). Fox control and rock-wallaby population dynamics - II. An update. *Wildlife Research* 25(1): 81-88.

Kinnear, J.E., Onus, M.L. and Bromilow, R.N. (1988). Fox control and rock-wallaby population dynamics. *Australian Wildlife Research* 15: 435-50.

Kinnear, J.E., Sumner, N.R. and Onus, M.L. (2002). The red fox in Australia—an exotic predator turned biocontrol agent. *Biological Conservation* 108(3): 335-359.

Krajewski, C. and Westerman, M. (2003). Molecular systematics of Dasyuromorpha. In *Predators with Pouches: The Biology of Carnivorous Marsupials* (eds. M. Jones, C. Dickman and M. Archer), pp. 3-20. CSIRO Publishing, Melbourne.

Krefft, G. (1866). On the vertebrated animals of the lower Murray and Darling, their habits, economy, and geographical distribution. *Transactions of the Philosophical Society of New South Wales* 1862-1865: 1-33.

Marlow, N.J., Thomas, N.D., Williams, A.A.E., Macmahon, B., Lawson, J., Hitchen, Y., Angus, J. and Berry, O. (2015). Cats (*Felis catus*) are more abundant and are the dominant predator of woylies (*Bettongia penicillata*) after sustained fox (*Vulpes vulpes*) control. *Australian Journal of Zoology* 63: 18-27.

Moore, G.F. (1884). *Diary of Ten Years Eventful Life of an Early Settler in Western Australia and also a Descriptive Vocabulary of the Language of the Aborigines.* M. Walbrook, London.

Morris, K.D. (2000). Fauna translocations in Western Australia 1971–1999: an overview. In *Biodiversity and the Reintroduction of Native Fauna at Uluru–Kata Tjuta National Park* (eds. J.S. Gillen, R. Hamilton, W.A. Low, & C. Creagh), pp. 64–74. Bureau of Rural Sciences, Canberra.

Morris. K., Orell, P. and Brazell, R. (1995), 'The effect of fox control on native mammals in the jarrah forest, Western Australia', in *Proceedings of the 10th Vertebrate Pest Control Conference Hobart, May 1995*, pp. 177–81, Department of Primary Industries and Fisheries, Tasmania: Hobart.

Power, V.L. and Monaghan, C. (2004). Numbats. In *Australian Mammals: Biology and Captive Management* (ed. S. Jackson). CSIRO Publishing, Collingwood.

Serventy, D.L. (1954). The recent increase of the rarer native mammals. V. Dryandra Forestry Station. *West Australian Naturalist*, 4:128–9.

Short, J., Turner, B., Parker, S. and Twiss, J. (1994). Reintroduction of endangered mammals to mainland Shark Bay: a progress report. In *Reintroduction Biology of Australian and New Zealand Fauna* (ed. M. Serena), pp. 183–8, Surrey Beatty & Sons, Chipping Norton.

Smales, L.R. (1997). *Multisentis myrmecobius*, gen. et sp. nov. (Acanthocephala: Oligacanthorhynchidae), from the numbat, *Myrmecobius fasciatus*, and a key to genera of the Oligacanthorhynchidae. *Invertebrate Taxonomy,* 11:301–7.

Vaughan-Higgins, R.J., Bradfield, K., Friend, J.A., Riley, T.V., and Vitali, S.D. (2013). Erysipelas in a numbat (*Myrmecobius fasciatus*). *Journal of Zoo and Wildlife Medicine* 44: 208-11.

Vieira, E.M., Finlayson, G.R. and Dickman, C.R. (2007). Habitat use and density of numbats (*Myrmecobius fasciatus*) reintroduced in an area of mallee vegetation, New South Wales. *Australian Mammalogy* 29: 17-24.

Waterhouse, G. R. (1841). Description of a new genus of mammiferous animals from Australia, belonging probably to the order Marsupialia. *Transactions of the Zoological Society of London* 2:149–154, plates 27–28.

Woinarski, J.C.Z., Burbidge, A.A. and Harrison, P.L. (2014). The action plan for Australian Mammals 2012. CSIRO Publishing, Collingwood.

Wood Jones, F. (1923) The Mammals of South Australia. AB James, Government Printer, Adelaide.

Wroe, S. and Musser, A. (2001) The skull of *Nimbacinus dicksoni* (Thylacinidae:Marsupialia). *Australian Journal of Zoology,* 49:487–514.

Youngson, W.K. and McKenzie, N.M. (1977). The wildlife of the proposed Karroun Hill Nature Reserve, Western Australia. *Department of Fisheries and Wildlife, Western Australia, Report* 30.

Zemann, A., Churakov, G., Donellan, S., Grützner, F., Fangqing, Z., Brosius, J. and Scmitz, J. (2013). Ancestry of the Australian termitivorous numbat. *Molecular Biology and Evolution* doi:10.1093/molbev/mst032

Personal Communication Reference Affiliations

B. Barton – WA Department of Park and Wildlife, Warren Region.

A. Carter – Australian Wildlife Conservancy, NSW

J. Calaby – CSIRO Wildlife Survey Section, Canberra

J. Cathcart – Australian Wildlife Conservancy, NSW

J.A. Friend – WA Department of Parks and Wildlife, Science and Conservation Division

M. Hayward – Australian Wildlife Conservancy, NSW

F. L'Hotellier – Australian Wildlife Conservancy, NSW

B. Macmahon – WA Department of Parks and Wildlife, Wheatbelt Region

N. Marlow – WA Department of Parks and Wildlife, Science and Conservation Division

K. Pollock – Murdoch University

L. Pope – Earth Sanctuaries

D. Taggart – University of Adelaide

N. Thomas – WA Department of Parks and Wildlife, Science and Conservation Division

I. Wilson - WA Department of Parks and Wildlife, Warren Region