MARSUPIAL CRC

000429

Mammal Conservation in Western Australia

THE LIBRARY
DEPARTMENT OF CONSERVATION
& LAND MANAGEMENT
WESTERN AUSTRALIA

VB CRC
VERTEBRATE BIOCONTROL
C R C

Conservation and Land Management

PERTH ZOO

CONSERVATION LIBRARY, KENSINGTON
000429
599
(941)
MAM
Mammal conservation in Western Australia : 28-29th November, 1996, Perth Zoo / Marsupial CRC ... [et al.]
DEPARTMENT OF ENVIRONMENT AND CONSERVATION

000429

Mammal Conservation in Western Australia
28-29th November 1998
Perth Zoo

THE LIBRARY
DEPARTMENT OF CONSERVATION
& LAND MANAGEMENT
WESTERN AUSTRALIA

Program

Saturday 28th November

8.45:	Registration
9.15:	Welcome

General Overview Session

9.30-10.00:	An Overview of threatened species recovery (Dr Andrew Burbidge, CALM)
10.00- 10.30:	Conservation Status and Threatening Processes. (Peter Mawson, CALM)
10.30-11.00:	**Morning Tea**

Protective Measures Session

11.00-11.20:	Operation Western Shield (Keith Morris, CALM)
11.20-11.40:	Cat Control (Dave Algar, CALM)
11.40-12.00	Project Eden (Keith Morris, CALM)
12:00-12:30	Panel Discussion
12.30-1.30:	**Lunch**

The Marsupial Cooperative Research Centre at Perth Zoo

1.30-3.00: Behind the Scenes Tours and Talks on Captive Breeding Programs.
(Dr Helen Robertson and Keeping Staff, Marsupial CRC & Perth Zoo)

1.30 – 2.15
Group A: Chuditch and Wopilkara
Group B: Numbat, Dibbler and Djoongari

2.15 – 3.00
Group A: Numbat, Dibbler and Djoongari
Group B: Chuditch and Wopilkara

3.15-3.45:	**Afternoon Tea**
3.45 – 4.15	Conservation Genetics. (Dr Peter Spencer, Marsupial CRC & Perth Zoo)
4.15 – 4.45	Social attitudes, Politics, Philosophy and Conservation of Marsupials (Professor Des Cooper, Marsupial CRC & Macquarie University)
4.45 - ?	Group discussion on day's issues. (Wine and Cheese)

Sunday, 29th November

Conservation Case Studies Session

9.00 - 9.20:	Reintroduction of threatened species (Keith Morris, CALM)
9.20 – 9.40:	Numbat (Neil Thomas, CALM)
9.40 – 10.00:	Chuditch (Brent Johnson, CALM)
10.00 – 10.20	The Dibbler (Dr Tony Start, CALM)
10.20-10.50:	**Morning Tea**

Health Issues Session

11.00 – 11.20	Health monitoring in the field (Dr Sherri Huntress, Perth Zoo)
11.20 – 11.40	Marsupial Diseases and Conservation (Professor Des Cooper, Marsupial CRC & Macquarie University)
11.40 – 12.00	Case Study – Wopilkara (Professor Des Cooper, Marsupial CRC & Macquarie University)
12.00-12.30	Panel Discussion
12.30-1.30:	**Lunch**

Mammal Conservation – Environmental Issues Session

1.30 – 2.00	Development of Protocols for Habitat Restoration (Grant Wells, King's Park/UWA)
2.00 – 2.30	Mining Company Involvement Alcoa Case Study (John Gardner)
2.30 – 3.00	Mining Company Involvement Hamersley Iron Case Study (Stuart Anstee)
3.00 - 3.30:	**Afternoon Tea**

Future Options Session

3.30 – 4.00	Fox and Cat Control (Dr Lyn Hinds, VB-CRC & CSIRO)
4.00 – 4.30:	Controlling Marsupial Breeding as a Conservation Tool (Professor John Rodger, Marsupial CRC & Macquarie University)
4.30 - 5.00:	Group discussion on day's issues.
5.00	**Close**

AN OVERVIEW OF THREATENED SPECIES RECOVERY

Andrew A. Burbidge, Department of Conservation and Land Management, WA Threatened Species and Communities Unit, PO Box 51, Wanneroo, WA 6065. Telephone (08) 9405 5128, fax (08) 9306 1066, Email andrewb@calm.wa.gov.au.

THE EXTINCTION CRISIS

Species are becoming extinct throughout the world at an alarming rate. While extinction is a natural process, the present rate is well above the natural background rate and is mostly due to human actions. Preventing the loss of threatened species and ecological communities is the cutting edge of the conservation of biological diversity. Other biodiversity conservation actions, such as conservation through reservation and the protection of natural bush on private land, are necessary to prevent species and communities from becoming threatened.

The theme of this weekend is mammal conservation but mammals, although an obvious and high profile group, comprise only a very small proportion of the total number of species on Earth. To put mammal conservation into context in Australia, threatened mammals comprise only 4.3% of species listed as threatened at the Commonwealth level.

Table 1. Number of Endangered, Vulnerable and Extinct species listed in Schedule 1 of the Commonwealth *Endangered Species Protection Act 1992*.

	Endangered	Vulnerable	Extinct
Invertebrates	0	3	0
Fish	11	10	0
Amphibians	13	3	0
Reptiles	12	40	0
Birds	34	62	23
Mammals	36	21	19
Non-vascular plants	1	0	0
Vascular plants	372	700	68
Totals	**479**	**840**	**110**

Table 2. Number of threatened and extinct taxa listed pursuant to the Western Australian *Wildlife Conservation Act 1950*, as at May 1998.

	Plants	Animals	Total
Presumed Extinct	23	13	36
Critically Endangered	95	12	107
Endangered	128	25	153
Vulnerable	104	88	192
Total threatened	**327**	**125**	**452**

Tables 1 and 2 show that most listed threatened species are vascular plants. Of the 125 listed threatened animal taxa in Western Australia, 33 are mammals (7% of listed taxa). Of the 12 Critically Endangered mammals in WA, three are mammals - Gilbert's Potoroo (single wild population at Two Peoples Bay), Antina or Central Rock-rat (not known to occur within the State) and the Mala or Rufous Hare-wallaby central Australian subspecies (no wild populations in WA, recently introduced to the Montebello Islands and a captive breeding colony established at Dryandra).

Tables 1 and 2 make it clear that most listed species are from comparatively well known groups - vertebrates and vascular plants. There are very few listed invertebrates and non-vascular plants, which together comprise well over 95% of living species. As our knowledge of these organisms improves it will be clear that many are extinct or threatened with extinction.

RECOVERY PLANNING AND ACTIONS

The conservation of threatened species in Australia is based on the 'recovery process':

1. Review conservation status of taxa,
2. Prepare priority lists of threatened species,
3. Conduct necessary research,
4. Produce costed Recovery Plans
   and for each Recovery Plan
5. Obtain funding,
6. implement, and
7. Monitor and review.

The key to the preparation and successful implementation of Recovery Plans is the setting up of a Recovery Team, comprising representatives of those that have a stake in the species' recovery from threatened to secure status. In Western Australia Recovery Teams are chaired by a senior CALM staff person and usually comprise land owners and managers, scientists with knowledge of the species, and representatives of local conservation groups, volunteers, local government and those funding implementation.

Recovery Plans must include an achievable objective (usually a change in status from critically endangered to endangered, endangered to vulnerable or de-listing) and criteria against which progress can be evaluated. It is important that the recovery actions prescribed in Recovery Plans are well thought through and cost-effective. Actions need to be carefully costed so that funding bodies know exactly what they are paying for and a responsible agency or person to implement each action must be shown. Recovery Plans need evaluation as they are implemented to ensure that they remain relevant.

SETTING PRIORITIES

With so many threatened species in Australia it is not currently possible to prepare and implement recovery plans for all of them. Setting priorities for the allocation of scarce resources is therefore very important.

In Western Australia, the World Conservation Union (IUCN) Red List Categories and Criteria are used to set priorities. The WA Threatened Species Scientific Committee allocated every listed taxon to one of the IUCN Categories of threat. It is CALM policy that recovery actions shall commence within one year of a taxon being allocated to Critically Endangered and that allocation being endorsed by the Minister for the Environment.

At the Commonwealth level a very similar approach is taken, with the Endangered Species Advisory Committee preparing 'Priority A' and 'Priority B' lists, closely equating to the IUCN Critically Endangered and Endangered categories.

Another Western Australian approach , particularly with plants, has been to conserve a number of threatened species within a particular area under the one plan. This multiple-species approach is becoming increasingly successful in areas, such as the agricultural areas of the south-west, where there are numerous threatened species.

Conservation Status of Mammals in Western Australia and Threatening Processes Affecting Them.

Peter R. Mawson
CALM, Wildlife Branch.
Locked Bag 104, Bentley Delivery Centre WA 6983.
e-mail: peterm@calm.wa.gov.au

Western Australia has a very rich mammal fauna with elements from both marsupial and eutherian families. Marsupials make up almost 40 percent and cetaceans a further 19 percent of the indigenous fauna. The total fauna includes 202 mammal species, comprising 184 indigenous species and 18 exotic species (Table 1). Only a few species of native mammal have benefited from the human-induced changes to the Australian landscape (eg large kangaroos *Macropus* sp.), although some smaller species may have been able to expand their range in the face of agriculture (eg Long-haired Rat *Rattus villissimus* into the Ord River Irrigation Area).

Table 1. Summary of Western Australian mammal fauna.

Monotremes	1 species
Marsupials	72
Bats	40
Rodents	33 indigenous, 4 exotic
Pinnipeds	2
Dugong	1
Cetaceans	35
Other Exotics	18
Total	202 species (184 indigenous, 18 exotic)

In general Australian native mammals have suffered declines in distribution and abundance as a result of changes to the environment following the arrival of European man. Ten indigenous mammal species (and 1 exotic) have become extinct since European settlement (Table 2). Somewhat surprisingly, the majority of the extinct species came from the central and northern desert regions of the State and the adjacent pastoral regions. Far fewer extinct species occupied the area now cleared for agriculture in the southwest of the State. In contrast, the south-west agricultural region has the highest number of species that are currently threatened with extinction. There are currently 33 indigenous mammal species listed as 'threatened fauna' under the provisions of the *Wildlife Conservation Act 1950*, with a further 10 species listed as 'presumed extinct' (Appendix 1).

This begs the questions - what are the processes that have lead to the extinction of our native mammals, and are they the same processes that are threatening our native fauna today?

Table 2. List of indigenous and exotic mammal families present in Western Australia, and showing their current conservation status. (Note: *Exotic families.)

Family		No. Species in Family	No. Species Threatened	No. Species Extinct
Tachyglossidae	Echidna	1	0	0
Dasyuridae	Dasyurids	31	6	0
Myrmecobidae	Numbat	1	1	0
Peramelidae	Bandicoots	6	2 (1 as spp.)	2
Thylacomelidae	Bilbies	2	1	1
Notoryctidae	Marsupial Moles	2	2	0
Vombatidae	Wombats	1	0	0
Potoroidae	Potoroos and Bettongs	4	2	1
Macropodidae	Wallabies and Kangaroos	18	6 (2 as spp.)	2
Phalangeridae	Possums	2	0	0
Petauridae	Sugar Gliders	2	0	0
Pseudocheiridae	Ringtail Possums	2	1	0
Burramyidae	Pygmy Possum	1	0	0
Tarsipedae	Honey Possum	1	0	0
Pteropidae	Flying Foxes, Fruit Bats	3	0	0
Emballonuridae	Sheathtail Bats	3	0	0
Megadermatidae	Ghost Bat	1	0	0
Hipposideridae	Leaf-nosed Bats	3	1	0
Vespertillonidae	Vespertilonid Bats	24	0	0
Mollossidae	Free-tail Bats	6	0	0
Muridae	Rodents	37 (incl. 4 exotic sp)	6	4
*Sciuridae	Palm Squirrel	1	0	0
*Leporidae	Rabbit	1	0	0
Ziphiidae	Beaked Whales	8	0	0
Physetidae	Sperm Whale	1	0	0

Family		No. Species in Family	No. Species Threatened	No. Species Extinct
Kogiidae	Pygmy, Dwarf Sperm Whales	2	0	0
Delphinidae	Dolphins	16	0	0
Balaenopteridae	Baleen Whales	6	4	0
Balaenidae	Baleen Whales	2	1	0
*Canidae	Dingo, Fox	2	0	0
*Felidae	Cat	1	0	0
*Mustelidae	Ferret	1	0	0
Otariidae	Seals, Sea lion	2	0	0
Dugongidae	Dugong	1	0	0
*Equidae	Horse, Donkey	2	0	0
*Suidae	Pig	1	0	0
*Camelidae	Dromedary Camel	1	0	0
*Bovidae	Cattle	2	0	0
*Cervidae	Deer, Antelope	2	0	1
*Capridae	Goat	1	0	0
	Totals	204	33 (3 as ssp)	11 (10 native, 1 exotic)

Within the general classification of 'threatened' fauna four categories are recognised. These categories are defined using internationally agreed criteria. Fauna defined as 'Extinct' are those for which there is no reasonable doubt that the last individual has died. Fauna is defined as 'Critically Endangered' if it is 'facing an extremely high risk of extinction in the wild in the immediate future'. Fauna is defined as 'Endangered' if it is 'facing a very high risk of extinction in the wild in the near future'. Those species defined as 'Vulnerable' are of those that are not Critically endangered or Endangered, but are facing a high risk of extinction in the wild in the medium-term future. These rankings help determine which species require remedial work as a priority and provide a standardized method by which the relative plight of unrelated species can be compared.

In Western Australia the IUCN rankings for threatened fauna (and flora) are reviewed annually by a CALM appointed expert scientific committee to ensure that the limited funds and resources are being directed at those species most in need. Those same criteria also help demonstrate when recovery actions have been successful, and allow species to be downgraded. It is the aim of all recovery programs to improve the conservation status of threatened species sufficiently to remove them from the threatened fauna list completely.

Table 3. Threatened native fauna declared under the provisions of the *Wildlife Conservation Act 1950*, according to IUCN rank (as of July 1998).

IUCN Rank	No. Species
Critically Endangered (CR)	2
Endangered (EN)	8
Vulnerable (VU)	23
Extinct (EX)	10
Total	43 (33 extant species + 10 extinct species)

In addition to the 43 species listed in Table 3, a further three species have recently been downgraded from VU to Lower Risk (Conservation Dependent) status. This rank identifies a species as no longer threatened, but acknowledges that if particular actions (such as control of predators) are not continued then the species would clearly decline again and most likely be returned to one of the threatened categories. The three lower risk (conservation dependent) species are the Woylie (*Bettongia penicillata ogilbyi*), Quenda (*Isoodon obesulus fusciventer*) and the Tammar wallaby (*Macropus eugenii derbianus*).

Threatening Processes

Threatening processes are those direct or indirect activities that lead to a reduction in the distribution and/or abundance of native species. Some processes are well known in their effects on native species, but others that are equally important are less well documented.

1. Habitat Loss

The most significant process threatening native fauna is loss of habitat. For terrestrial mammals this is most obvious in clearing of native vegetation for agriculture or building development. Habitat fragmentation can be equally damaging to populations of native mammals as it can prevent dispersal of juvenile animals into vacant habitat, or it can prevent re-colonization of areas after local populations have died out. Habitat fragmentation can also cause declines in abundance because the carrying capacity of remnant habitat varies with the seasons and over time as the vegetation community progresses towards the climax stage. This means that at some times small fragments can sustain populations of mammals, but at others the populations decline and may even die out due to lack of resources.

2. Predation

Predation of native fauna by exotic mammals is considered to have been an important contributing factor in the extinction process for the ten species of native mammal listed in Table 2. Australian mammals have evolved in the presence of few large carnivores and most show little or no predator avoidance behaviour. Predation has its greatest impacts on those species that have naturally restricted distributions (eg island populations), or those populations that are normally at low levels of abundance. The potential for native mammals to recover from the effects of predation is influenced largely by their reproductive capacity, and the productivity of their environment.

3. Disease

Disease is a naturally occurring process in the life cycle of most native mammals. There are a number of native diseases that affect native mammals (eg kangaroo viral blindness, lumpy jaw, psittacine beak and feather disease, and *Salmonella*), and these seldom have any long-term affect on mammal populations. However, along with the exotic mammals that European man has brought to Australia have come exotic diseases. Diseases such as *Toxoplasmosis gondii* that is typically transmitted by feral cats can have significant impacts on native species such as bandicoots. Other diseases, like *Mycobacterium tuberculosis* have been found to cause mortality in fur seals and sea lions. Disease has been suggested as playing a major role in the decline in several mammal populations in southwest WA in the early part of this century, at a time prior to the arrival of the fox in this region.

4. Competition

Competition for food and shelter is also believed to play in a role in the decline in native mammal populations. The plagues of rabbits that swept across southern Australia in the late part of last century, often following on from high stocking rates of domestic sheep and cattle had a significant and long lasting impact on native vegetation, much of which never fully recovered. The effects of competition for food and shelter are greatest when resources are most limited [eg during drought, after extensive fires or when combined (native + exotic fauna) carrying capacity of the land is exceeded]. Competition is also important in situations where the native mammals are slow to mature and breed, but the exotic competitor matures at a young age and breeds prolifically, or year-round.

5. Altered Fire Regimes

Australian ecosystems are recognised as being nutrient impoverished. Most of the available nutrients are locked up in the above ground components of native plants. These nutrients are only released by fire. In most plant communities there is a requirement for a minimum period of time between fires to allow the plants to mature and set seed. Too frequent fires prevent many species from setting seed, favouring those species that regenerate from below ground roots, tubers or lignotubers. If the frequent burning pattern is continued the vegetation can become dominated by a different suite of plants, and the resultant habitat may no longer be suitable for some native mammals.

Protracted intervals between fires can also create problems. Many Australian plants are adapted to fire and require hot fires in autumn (or the end of the dry season) to release seeds held in woody pods, or to stimulate germination. If fire is excluded from the local environment, fire-dependant plant species may decline in numbers (although they may still be present in the soil seed bank). Many of these species provide important food and shelter for native mammals.

Fire exclusion in some plant communities can also lead to infrequent but high intensity wildfires that burn over very large areas. If the areas burnt out are too large, it becomes very difficult for native mammals to recolonise the vacant habitat that regenerates simply because they do not have the capacity to disperse such large distances. This problem does not arise if the fires are smaller in area and leave a patchwork mosaic of burnt, partially burnt and unburnt habitat. Small numbers of mammals can survive in the unburnt habitat and then quickly recolonise the burnt areas as they regenerate.

6. Altered Hydrology

Western Australia has only one mammal species that is entirely dependent on a freshwater environment. The Water rat (*Hydromys chrysogaster*) has declined in numbers and distribution in the highly modified parts of the southwest of the State. Removal of fringing vegetation along river and stream banks has lead to a decline in habitat quality with increased turbidity of water and a reduction in important food sources associated with the riparian vegetation.

Removal of deep-rooted native vegetation from much of the southwest landscape and its replacement with shallow-rooted exotic annuals has lead to the water tables rising close to the surface. As the water tables have risen they have brought large salt loads with them. In many places in the wheatbelt the salt has reached the soil surface and then been transported across the land and into lakes, rivers and streams. The salinization of our freshwater bodies has lead to the loss of important food sources that the Water rat was dependent on. Rising water tables, in the absence of excessive salt loads can also lead to the loss of important habitat through water-logging. This is most obvious in woodlands surrounding perched water tables, or in areas with underlying clay soils.

7. Pollutants

Many of the chemicals developed by humans to improve agricultural production can have serious effects on non-target species. Most people will be familiar with the problems caused by insecticides such as DDT which were developed to control insects in crops but also lead to the decline in many species of birds, even ones that did not feed directly on insects (eg Peregrine Falcon *Falco peregrinus*).

Chemical pollutants invariably have their greatest impacts on those species at the top of the food chain, and in those that are long-lived and which reproduce slowly. Research is showing that many species of cetaceans are accumulating very high levels of heavy metals and highly toxic pollutants such as poly-chlorinated biphenyls (PCBs). These chemical contaminants can lead to death in their own right, reduced fertility, increased juvenile mortality and reduced natural immune response.

The impacts caused by pollutants are likely to very long lasting as many of these chemicals do not break down readily in the environment.

8. Hunting

Predation by humans has been directly responsible for the extinction of several species of animal around the world, particularly those with restricted distributions (eg Dodo, Stella's Sea Cow), but also for those species that were very abundant and widespread (eg Passenger Pigeon).

Commercial hunting of several of the great whale species including three species found in waters off Western Australia (Blue whale *Balaenoptera musculus musculus*, Humback whale *Megaptera novaeangliae* and Southern right whale *Eubalaena australis*) almost lead to their extinction. Intensive unregulated hunting of several of our native pinniped species (New Zealand fur seal *Arctocepahlus forsteri* and Australian sea lion *Neophoca cinereus*) also lead to serious declines in populations which these species are only now beginning to recover from.

All of the native mammal species that are the subject of commercial harvesting in Western Australia are taken according to carefully regulated management programs (eg Red kangaroo *Macropus rufus*, Western Grey kangaroo *M. fuliginosus* and Euro *M. robustus* and Saltwater and Freshwater crocodiles *Crocodylus porosus* and C. *johnstoni*). These management plans are designed to ensure that the level of harvesting does not lead to any declines in the wild populations.

Further Reading

Burbidge, A.A. (1985). Fire and mammals in hummock grasslands of the arid zone. In: *Fire Ecology and Management of Western Australian Ecosystems.* (ed. J.R. Ford) pp. 91-4. Environmental Studies Group Report No. 14, Western Australian Institute of Technology, Perth.

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

McFarlane, D.J.a nd George, R.J. (1992). Factors affecting dryland salinity in two wheatbelt catchments in Western Australia. *Aust. J. Soil Res.* 30, 85-100.

Morton, S.R. (1990). The impact of European settlement on the vertebrate animals of arid Australia: a conceptual model. *Proc. Ecol. Soc. Aust.* 16, 201-13.

Wells, K.F., Wood, N.H. and Laut, P. (1984) Loss of forests and woodland in Australia: A summary by State, based on rural local government areas. Technical Memorandum 84/4, CSIRO Institute of Biological Resources. Division of Water and Land Resources, Canberra.

Appendix 1. Threatened and presumed extinct native mammal fauna in Western Australia (as of July 1998).

SCHEDULE 1 --- FAUNA WHICH IS RARE OR LIKELY TO BECOME EXTINCT

Mammals

	Scientific Name	*Common Name*
1.	*Balaenoptera borealis*	Sei Whale
2.	*Balaenoptera musculus musculus*	Blue Whale
3.	*Balaenoptera physalus*	Fin Whale
4.	*Bettongia lesueur*	Burrowing Bettong or Boodie
5.	*Dasycercus cristicauda*	Mulgara or Minyi-minyi
6.	*Dasycercus hillieri*	Ampurta
7.	*Dasyurus geoffroii*	Chuditch or Western Quoll
8.	*Eubalaena australis*	Southern Right Whale
9.	*Isoodon auratus auratus*	Golden Bandicoot or Wintarru
10.	*Lagorchestes conspicillatus conspicillatus*	Barrow Island Spectacled Hare-wallaby
11.	*Lagorchestes hirsutus*	Rufous Hare-wallaby or Mala
12.	*Lagostrophus fasciatus*	Banded Hare-Wallaby or Muning
13.	*Leporillus conditor*	Greater Stick-nest Rat
14.	*Macropus robustus isabellinus*	Barrow Island Euro
15.	*Macrotis lagotis*	Dalgyte or Bilby or Ninu
16.	*Megaptera novaeangliae*	Humpback Whale
17.	*Mesembriomys gouldii gouldii*	Black-footed Tree-rat
18.	*Myrmecobius fasciatus*	Numbat or Walpurti
19.	*Notoryctes caurinus*	Northern Marsupial Mole or Kakarratul
20.	*Notoryctes typhlops*	Southern Marsupial Mole or Itjaritjari
21.	*Parantechinus apicalis*	Dibbler
22.	*Perameles bougainville*	Western Barred Bandicoot
23.	*Petrogale lateralis*	Black-footed Rock-wallaby or Warru
24.	*Phascogale calura*	Red-tailed Phascogale
25.	*Potorous gilbertii*	Gilbert's Potoroo
26.	*Pseudocheirus occidentalis*	Western Ringtail Possum
27.	*Pseudomys australis*	Plains Rat
28.	*Pseudomys fieldi*	Shark Bay (or Alice Springs) Mouse
29.	*Pseudomys shortridgei*	Heath Rat
30.	*Rhinonicteris aurantius*	Orange Horseshoe Bat
31.	*Setonix brachyurus*	Quokka
32.	*Sminthopsis psammophila*	Sandhill Dunnart
33.	*Zyzomys pedunculatus*	Central Rock-rat or Antina

SCHEDULE 2 --- FAUNA PRESUMED TO BE EXTINCT

Mammals

	Scientific Name	*Common Name*
1.	*Chaeropus ecaudatus*	Pig-footed Bandicoot or Kantjilpa
2.	*Lagorchestes asomatus*	Central Hare-wallaby or Kuluwarri
3.	*Leporillus apicalis*	Lesser Stick-nest Rat
4.	*Macrotis leucura*	Lesser Bilby or Tjunpi
5.	*Notomys amplus*	Short-tailed Hopping Mouse or Yoontoo
6.	*Notomys longicaudatus*	Long-tailed Hopping-mouse
7.	*Notomys macrotis*	Big-eared Hopping-mouse
8.	*Onychogalea lunata*	Crescent Nailtail Wallaby or Tjawalpa
9.	*Perameles eremiana*	Desert Bandicoot or Walilya
10.	*Potorous platyops*	Broad-faced Potoroo

WESTERN SHIELD FAUNA RECOVERY PROGRAM

Keith Morris
CALMScience Division
Department of Conservation and Land Managment

INTRODUCTION

Over the last 20 years or so, Department of Conservation and Land Management (CALM) scientists have been able to demonstrate that fox predation is one of the primary causes in the decline of medium sized mammals in WA, and the same is probably true for other parts of Australia. Foxes followed the spread of rabbits from Victoria and arrived in the eastern parts of WA around 1910, and had reached the south west corner by 1930 (King and Smith 1985). Many mammals declined or became extinct soon after, although some had disappeared before this time and cat predation may have been a significant factor in this earlier decline, particularly among rodents. WA is fortunate in that the mammal fauna is largely resistant to the toxin sodium fluouroacetate, or 1080 (King *et al* 1978, 1981). This toxin occurs naturally in many species of *Gastrolobium* plants, primarily in the south west of the State and the fauna has evolved a resistance to it, enabling them to continue eating the plants despite this defence mechanism. Generally the herbivores have a higher tolerance than the carnivores. The introduced canids (and felids) are particularly susceptible to 1080 (McIlroy 1981) and this toxin can be delivered in dried meat baits at levels which are lethal to foxes but not to native mammal species. By reducing fox abundance by 80-90%, remnant populations of threatened mammals can increase in number and expand their ecological niche.

Christensen (1980) suggested that fox predation was restricting Woylies (*Bettongia penicillata*) to *Gastrolobium* thickets in the south west Jarrah forests, but it was not until the late 1980's that Kinnear *et al* (1988) demonstrated experimentally that foxes were limiting remnant rock wallaby populations. He showed that populations of the Black-footed Rock wallaby *Petrogale lateralis* that were subject to fox control increased in abundance and started foraging over wider distances, while those without fox control went to extinction. It has also been demonstrated that the Woylie abundance at Tutanning Nature Reserve and Brushtail Possum abundance at Boyagin Nature Reserve increased in the areas where fox control had been implemented (Kinnear *pers comm*). Friend (1990) showed a similar increase in Numbat (*Myrmecobius fasciatus*) abundance at Dryandra following fox control.

In 1991 CALM commenced some work on the Chuditch (*Dasyurus geoffroii*) in the Batalling forest to determine the impact of fox control on this threatened carnivorous species that was potentially at risk from 1080 poison baits. The Chuditch was known to have an LD_{50} for 1080 of approximately 7.5 mg/kg (King *et al* 1989) and by consuming two baits, an average-sized adult could receive a lethal dose (Twigg and King 1991). 1080 has also been shown to have some sub-lethal effects on mammals through sterility in males. Ten Chuditch were radiocollared at Batalling and followed through two operational fox baitings (one every 3 months) which covered approximately 10 000 ha. No mortality was recorded and no impact on breeding was detected - all females continued to produce the normal number of pouch young. This population has subsequently increased and expanded into areas where Chuditch did not occur in the presence of foxes (Figure 1). It was clear that the fox predation and also competition for food, were primary factors in the low abundance of Chuditch in the Jarrah forest. Other species of medium sized mammals at Batalling also benefited from this fox control program. Populations of Woylie (Figure 2), Quenda (
increased and expanded their distribution within the forest. Primarily because of fox

control and the subsequent expansion of populations, the Woylie was removed from State and Commonwealth threatened fauna lists in 1996 (Start *et al* 1996).

BROADSCALE FOX CONTROL

Once it became clear that fox control using dried meat baits did not pose a problem to Chuditch in the Jarrah forest the way was clear to commence broadscale fox control in this area. This program was called Operation Foxglove and it commenced in 1993 with financial assistance from Alcoa. Fox control was implemented over 440 000 ha and its aim was to expand existing remnant populations of threatened mammals such as the Woylie, Quokka, Tammar, Chuditch and Ringtail Possum. This scale of baiting also provided the opportunity to examine the effectiveness of different baiting regimes in terms of fauna recovery. CALM was interested in determining whether 2, 4, or 6 baitings a year over large areas were as effective in fauna recovery. [2 baitings 221 000 ha; 4 baitings 130 400 ha; 6 baitings 89 000 ha; unbaited 103 500 ha] At the same time the Vertebrate Biocontrol CRC was interested in determining what level of fox control was necessary to elicit a fauna response and a partnership was struck with the CRC and Environment Australia to support this high cost work. Forty three monitoring sites (trapping grids) plus sand pad monitoring sites were established, with representation in each of the baiting regimes plus the unbaited area. As fauna number were low throughout most of the forest at this time he undertook translocations of Woylies to the treatment sites and compared survivorship in each. This work is continuing however some trends are apparent. When boundary and core sites are combined, Woylie survivorship in the 6 baited area is greater than in the other treatments.
In the core areas, Woylie survivorship in the 6 baited area was greater than in other treatments, but in boundary areas there was no difference in survivorship (de Tores 1996).

The success of Operation Foxglove in fauna recovery led to a more ambitious program of fox control covering most of CALM's estate (about 5 000 000 ha). Again WA is fortunate in that although several mammal species have declined significantly, remnant populations still occurred in the south west forests, or on islands and these could serve as founder populations for fauna recovery. This larger program was called Western Shield and was launched in early 1996 (Bailey 1996). The strategy was to lay baits aerially over large areas of conservation reserve and forest, targetting areas with remnant populations of threatened species and area identified as suitable for translocating threatened species. It aimed to return 23 species, mainly threatened mammals, birds and reptiles to 20 sites throughout the south west of WA over the next 10 years. The annual budget is approximately $ 1.9 million, and assistance will be sought from private sector sponsorship.

Western Shield will initially only cover about 4 000 000 ha of CALM land in the south west of WA that lies on the high rainfall side of the 350 mm isohyet. Previous experience has shown that where foxes are controlled in more arid environments, feral cat numbers increase and become a limiting factor in wildlife recovery (Christensen and Burrows 1995, Friend and Thomas 1995). Research on effective control methods for feral cats is currently under way and a moist bait has been developed, but unlike the dried meat bait, it is palatable to native species. The focus is now on determining a felid specific toxin, and once this becomes operational and non-target impacts determined, fox and cat baiting will be expanded to the more arid areas of WA. An exception to this is the 100 000 ha Peron Peninsula where much of the research into cat control is being undertaken. It is anticipated that cats will be under control by the end of 1997 and we plan to translocate 10 species of threatened mammal and the Mallee Fowl onto Peron Peninsula over the next five years.

Translocations under Western Shield commenced in November 1995 with the reintroduction of Numbats to Dragon Rocks Nature Reserve. In 1996 Woylies were reintroduced to the Jarrah forest near Mundaring, on the outskirts of the metropoloitan area, and Chuditch and Woylies were reintroduced to Lake Magenta Nature Reserve in the eastern wheatbelt.

FOX BAITING METHODOLOGY

Currently 4.5 mg 1080 is injected into 120g fresh meat baits which are then dried to approximately 70 g, with a texture like biltong. These baits are distributed, either from the air or from the ground at a density of 5 per square kilometre, at a frequency of four time a year, although baiting frequency does vary depending on the situation. The smaller wheatbelt reserves such as Dryandra are baited from the ground monthly, others such as Dragon Rocks (40 000 ha) where Numbats have recently been reintroduced are baited aerially every two months. Larger reserves such as Lake Magenta (100 000 ha) are baited aerially every three months, however this needs to be supported with more frequent ground baitings in late summer and early autumn while the young foxes are dispersing and occupying territories vacated by foxes killed previously by baiting.

The technique used involves a twin engined aircraft flying at 1 000 feet at 150 kts on 1 km transects. Baits are dropped every 200 m, and the aircraft can drop 1 000 baits an hour. The annual cost of this, including baits, aircraft and salaries is 24 cents/ha.

CALM has produced a Fox Control Manual (CALM 1996) which provides the operational guidelines for fox control on CALM lands. This covers the background to why we fox bait, what fox baits are to be used, how they are to be laid and what public notification is required.

THE FUTURE

Western Shield will be expanded into more arid areas once feral cat control becomes operational. The key to this program in WA will be the continued acceptance by the public in the use of 1080 and the ability to use any cat bait and felid specific toxin that is developed. While public support for fox control in WA has been good to date, the ability to control foxes and cats of such great importance to our wildlife conservation programs that research that examines alternative methods, such as sterility control, should also be supported. Other States are now examining the possibility of similar fauna recovery programs to Western Shield and CALM is well placed to be able to offer advice and expertise to implemnet these. Although several native species in the eastern States do have relatively low tolerances to 1080, there are only a few that would probably be at risk. This risks reduced further if the level of 1080 is reduced and larger baits used. The most obvious at risk are the quolls. At 3 mg of 1080 per bait both the Eastern and Tiger quoll would have to consume a whole dried bait to receive an LD_{50} dose. Experience with Chuditch suggests that quolls don't consume dried meat baits, but do like the moister Fox - off or similar baits. Chuditch once occurred in western NSW and we already know that Chuditch are not affected by 1080 dried meat baits, so reintroduction programs in the future could be a reality providing fox control was in place. There is also enormous potential for ecotourism to be developed as part of fauna recovery programs and this can serve as a source of funding to continue baiting and monitoring work.

REFERENCES

Bailey, C. (1996). Western Shield - bringing wildlife back from the brink of extinction. *Landscope* Vol 11 (4) pp 41-48. Department of CALM, Perth., WA.

CALM (1996). Fox Control Manual. Operational guidelines for the control of the Red Fox Vulpes vulpes through the use of sodium monofluoroacetate or 1080 on CALM managed estate and in other CALM programs. Department of CALM, Como, WA

Christensen, P.E.S. (1980). A sad day for native fauna. *Forest Focus* 23:2-2. Forest Department, Perth, WA.

Christensen, P. and Burrows, N. (1995). Project desert dreaming: the reintroduction of mammals to the Gibson Desert. In (Ed) Serena, M. *Reintroduction Biology of Australia and New Zealand fauna.* Surrey Beatty and Sons, Chipping Norton, NSW.

de Tores, P. (1996). Prey response to 1080 baiting over large areas. Progress report to ANCA, June 1996.

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

Friend, J.A., and Thomas, N.D. (1995). Reintroduction and the Numbat recovery programme. In (Ed) Serena, M. *Reintroduction Biology of Australia and New Zealand fauna.* Surrey Beatty and Sons, Chipping Norton, NSW.

King, D.R. and Smith, L.A. (1985). The distribution of the European Red Fox (*Vulpes vulpes*) in Western Australia. *Records of the Western Australian Museum* 12 (2): 197-205.

King, D.R., Oliver, A.J. and Mead, R.J. (1978). The adaptation of some Western Australian mammals to food plants containing fluoroacetate. *Australian Journal of Zoology* 26: 699-712.

King, D.R.,Oliver, A.J. and Mead, R.J. (1981). *Bettongia* and fluoroacetate: a role for 1080 in fauna management. *Australian Wildlife Research* 8: 529-536.

King, D.R., Twigg, L.E. and Gardner, J.L. (1989). Tolerance to sodium monofluoroacetate in dasyurids from Western Australia. *Australian Wildlife Research* 16 : 131-140.

Kinnear, J.E., Onus, M.L. and Bromilow, R.N. (1988). Fox control and rock-wallaby population dynamics. *Australian Wildlife Research* 15 : 435-450.

McIlroy, J.C. (1981). The sensitivity of Australian animals to 1080 poison. II Marsupial and eutherian carnivores. *Australian Wildlife Research* 8 : 385-399

Start, A.N., Courtenay, J. and Morris, K.D. (1996). It's back: the return of the Woylie. *Landscope* Vol 11 (3). pp 10-15. Department of CALM, Perth, WA.

Twigg, L.E, and King, D.R. (1991). The impact of fluoroacetatebearing vegetation on native Australian fauna : a review. *Oikos* 61: 412-430.

Cat Control

Dr David Algar

Abstract
Feral cats are widely recognised as a serious threat to populations of small to medium sized native vertebrates in Australia. Predation by cats has resulted in the local extinction of a number of species on islands and mainland Australia and may affect the continued survival of many others persisting at low population levels. A number of reintroduction programs have also suffered because cat predation has significantly reduced the survival of the reintroduced species. Control of feral cats is widely recognised as one of the most important conservation issues in Australia today.

Until recently, limited research has been conducted on control strategies for feral cats. The Department of Conservation and Land Management (CALM) has developed a research program to provide an effective and cost efficient strategy to control feral cats as part of the umbrella program 'Western Shield'. Broad scale baiting offers the best option to control feral cats in strategic areas. A series of trials have been conducted to develop a bait that is highly acceptable to feral cats. Field trials are now being conducted to test the efficacy of this bait across geographic zones and to optimise control strategies.

In this presentation, the bait research for feral cat control will be outlined. Also, techniques that have been developed to test baiting effectiveness will be discussed.

22.10.98

THE NUMBAT
(*Myrmecobius fasciatus*)

Introduction
The Perth Zoo and the Department of Conservation and land Management formed a co-operative breeding program in 1987.The Recovery Plan for the Numbat was formulated in 1994 and it defines the management actions to support recovery of the Numbat . During the early days of European colonisation of Australia , the species ranged over much of the southern part of the Australian continent . Since then the species has under gone a dramatic reduction of its range and is now adays only known to naturally exist in several isolated areas in the south-west of Western Australia.

Reason for the decline
- changes in to fire regimes, especially in the arid zone.
- destruction of habitat.
-predation by introduced carnivores - the Red Fox (Vulpes vulpes) and the cat (Felis catus)

General Biology

The Numbat is a diurnal , terrestrial, termite-eating marsupial of approximately 500-550 g in weight. The coat is a red-brown colour above, paler below , with darker rump and prominent , white, transverse bars. The head is narrow with a sharp snout and horizontal eye-stripe.The tail has long hairs which often erect to look like a bottle brush.
There is little sexual dimorphism between the sexes, although males tend to be slightly heavier than females. There is a seasonal development of the sternum gland in the male which enlarges and discharges a ochre coloured substance. Females have 4 nipples, but no pouch.

Husbandry

Diet
Numbats in the wild consume up to 20,000 termites a day. At the Perth Zoo a termite trapping technique has been developed to supply quantities of termites to supplement the Artificial diet. The artificial diet consists of a lactose free milk formula blended with eggs which is cooked to the consistency of a custard. Additional vitamins , calcium and sterilised termite mound and sand are added when cooled. Each animal is feed twice a day 45gm of artificial diet with 5 gms of live termites sprinkled on top. The quantity varies through out the year depending on body weight. The diet is changed to a 60-100% termites diet through out the breeding season.

Housing

There are 2 rows of 12 interconnecting enclosures designed to housed 6 breeding pairs. The entire complex is meshed to 1 metre below ground and continues along the floor. There is a visual screen erected between all enclosures creating a visual barrier between the Numbats. Each enclosure has access doors between them which can be open and closed as required.

As Numbats are solitary animals in the wild , they are keep separated through out the year until breeding season. They remain separated until early pro-oestrus is detected in the female and sperm production is detected in the male, then a gate between the enclosures is open allowing them free access with their partner.

Breeding

During the breeding season urine sampling of both male and females is carried out on a fort nightly basis.The shed epithelial cells are stained to allow histological assessment of their phase of oestrus determined by the epithelial cell morphology. Sperm production is detected using the same methods. Detailed behavioural observations are also undertaken on a daily basis . Most matings take place during the day and often in the open. Females remain in oestrus over a 48 hr period during which several matings will occur . Matings have been observed as short as a few minutes and as long as 60 minutes. A seminal plug is often passed 24-48 hours after the mating, which is a good indicator of a successfully mating.

Pouch young are born 14 days after mating and remain in the pouch until July then are deposited into a under ground burrow. At the Perth Zoo Lactating females and young are transferred inside a wintering building with special nest boxes for the mothers to deposit their young. They remain inside until they have been successfully weaned onto the artificial diet then are transferred back out side in early October. The reseason for moving females inside is for better management of young eg. can regularly inspect young in box and weigh to evaluate their growth and condition.

Developmental time line of 100 F young.

22.1.97	Birth
28.5.97	Sexed
10.6.97	Fur growing
23.7.97	First deposited
24.7.97	Eyes still closed
28.7.97	Long guard hairs growing
2.8.97	First vocals heard
5.8.97	Young attached to nipple again
6.8.97	Eyes open first time
1.9.97	First emerged from box
23.9.97	First eats Artificial diet
30.10.97	Weaned from mother

Release Preparation

Young Numbat once weaned are provided with termite mound daily for enrichment and to encourage foraging. Several weeks before release they are placed onto a 100% termite diet instead of the artificial diet .The young Numbat are also exposed to one Predator (Bird of Prey) while housed in the tunnel and their response monitored. This is to encourage some predator recognition skills.

References

Friend, J.A. and Whitford, D (1988)Captive Breeding of the Numbat , Myrmecobius fasciatus. World Wildlife Fund Australia Project 50, final report. Department of Conservation and Land Management (unpublished)

Friend, J.A. and Whitford, D (1993) Maintenance and Breeding of the Numbat (Myrmecobius fasciatus) in Captivity. The Biology and Management of Australiasian Carnivorous Marsupials.

Power, V. Lambert, C. and Bradley, M. (1998) Studies on the Reproductive Biology of the Numbat (*Myrmecobius fasciatus*) in Captivity (unpublished)

Species Management Plan for Numbats for ARAZPA

CHUDITCH IN PERTH ZOO

By Glen Gaikhorst

DESCRIPTION

* The Chuditch or Western Quoll is Western Australia's largest carnivorous Marsupial.
* They are nocturnal, active from dusk to dawn but have been noticed foraging on dull winter days. They also like to sun bake.
* They have a brown pelt which is covered with 50 to 70 white spots. The spots are randomly scattered and the arrangement is unique to each animal. Their tail is long and black.
* The average Chuditch is about the size of a small cat. A male Chuditch weighs about 1400grams and a female about 900grams.

CLASSIFICATION

* Chuditch were classed as rare and endangered but now have been down-listed to Vulnerable. This means secure in the wild but human intervention help is still needed. ie continuing predator control (foxes and cats).

PERTH ZOO'S ROLE

* Breed for release, as per recovery plan. Have close liaisons with CALM on numbers needed etc. All the animals are the property of CALM.
* Education
* Development of husbandry and working practices for each species. Maintain good genetics within our breeding colony using studbooks.

BREEDING

* Breeding season from April to July.
* Females build nests, become more secretive, and develop fat collars on their neck to help.
* Gestation 18 days where 2-6 young are born. They are about 5mm long (size of a grain of rice).
* They are in the pouch for 61 days then are deposited into the nest. At this stage they are just starting to get fur and spots are noticeable. Their eyes are closed and they cannot yet maintain body temperature.
* At 110 days old their eyes are open, they are fully furred and can generate their own body heat. They start to wander around with their mother and start to eat their first solid foods.
* At 170 days old they are weaned from their mothers.
* To date we have bred 281 animals, and 207 of these have been released.

SOCIAL ORGANIZATION

* Chuditch are solitary animals only coming together for a short time in the breeding season.
* Home ranges; Males about 14 square kms and females about 9 square kms.
* Young disperse from Nov to Jan.

DIET

* Wild; insects, reptiles, birds and small mammals.
* Zoo;   mice, chicks, rats, fish and insects.

HABITAT

* Requires dense scrub or bush, Jarrah or Mallee. Do adapt well also to other habitats.
* They live in dens or other animals burrows, hollow logs, or granite out crop crevices.

DISTRIBUTION

* Now restricted to the south west of WA. Once were found in every mainland state except Vic.
* In 1994 was estimated less than 6000 animals left in the wild.

REFERENCES

* 1994 Chuditch Recovery Plan, Keith Morris, Peter Orrell. Conservation and Land Management.
* Mammals of Australia, R Strahan, Revised edition 1994.

The captive breeding and prerelease management of Djoongari (Shark Bay Mice) at Perth Zoo (1996-1998).

Introduction

In June 1996 six Djoongari were removed from Bernier Island, North Beach to establish a captive colony. These were initially held at the CALM Wildlife Research Centre, Woodvale. Here they produced five litters, bringing the total number of Djoongari to 25. These were then transferred to Perth Zoo in 1996 for captive breeding. Additional animals were obtained from Bernier Island in 1997 to increase the genetic pool of the captive population (three were received only one survived for breeding)
Animals from this captive population are to be used in future translocation.

Current status

Bernier Island: No decrease in their distribution or abundance, population estimated at 6000-8000 in1992.

Doole Island:	The translocated population has increased in size after its previous low numbers.
Herison Prong:	Currently there is no indication of the translocated population still persisting.
Peron Peninsula:	1998 release cancelled due to drought and the presence of cats.

Captive management

Temperature

Optimum temperatures range from 20 to 27 degrees, nothing over 30 degrees for extended periods.

Enclosures

Various aquariums are used with well fitting mesh lids. Sand is used as the base substrate with the addition of sea grass and plants such as Acacia and salt bush. The addition of sea grass and various plants was found necessary to provide cover and adequate substrate for the construction of raceways, nests and tunnels. This has proved important for security and environmental enrichment that may contribute to the reduction of aggressive behaviour. The use of tunnels seems more important during the breeding season. In addition PVC pipes and finch nest boxes are provided for nest sites and again to further enrich the environment.

Nutrition

Two diets are employed both a **Captive** and a **Release**. The release diet has been developed to help the individuals adjust to their natural environment prior to release and works on a four day rotational basis. In comparison to the Captive diet, the Release diet utilises succulents more as a water source and withholds the normal water supply twice every four days. Seeds such as Triodia are also supplied which they will find in their natural environment. An animal release weight of 35g is desirable.

Captive diet
Mixed budgie seed and pigeon mix 50:50
Sweet potato, apple and carrot weekly
Sunflower seeds, twice a week
Rodent cubes, three times a week
Fresh *Olearia axillaris* or *Spinifex longifolius,* twice a week
Salt Bush, *Atriplex spp* once a week
Succulent, Pig face or Sea spinach once a week

Release diet
Mixed budgie seed and pigeon mix 50:50
Sweet potato, broccoli **or** carrot once every four days
Sunflower seeds, once every four days
Fresh *Olearia axillaris* or *Spinifex longifolius,* once every four days
Succulent, Pig face or Sea spinach once every four days

Pre-release management

In addition to the above diet manipulation, it is also important to help them adjust to their new environment prior to release. To achieve this the nest boxes and PVC pipes are removed, while adding further sea grass and *Olearia axillaris* to provide a more natural environment. This stimulates more natural behaviour related to nest and race way building and therefore reduces an element of the total stress that will be experienced release.In final preparation all animals are weighed and presence of microchips confirmed

Reproductive management

Pairing

Similar size animals are paired, but not until they are at least three months old. They are both placed into a new environment, so neither animal is invading the other's territory. They then stay as a family unit and the male is **not** removed after copulation or birth, as this may result in the female aborting or eating her young. Also a post partum oestrus has been observed one day after birth and so minimal disturbance is important at this time.

Reproductive parameters
One to two litters in the wild, up to three in captivity.
Oestrus cycle 14-16 days.
Gestation period 28 days
Litters size two to six.

Stimulation of breeding

Breeding may possibly be stimulated by the ingestion of fresh green vegetation, a source of giberallic acid. This may be a possible area of future research.

Development of young

00 days:	Born Naked with ears folded down and eyes closed.
03 days;	Upper and lower incisors exposed.
11 days:	Well furred, ears free, eyes still closed.
15 days:	Eyes open.
30 days:	Weaned by approximately this age. Implanted with a Trovan microchip. Litters removed into separate aquaria. Sibling females can remain together until paired at 90-100 days
60 days:	Separation of males into separate tanks is necessary to avoid aggression
100 days:	Full adult size.

<u>Animal Health</u>

Ectoparasites have been found on Djoongari and have been treated successfully with 'Frontline".

Fatalities have occurred from stress caused by handling, while fighting and injuries sustained from this, are also another cause.

Possibly allergic to penicillin.

Captive longevity 2.6 years.

<u>Animal Handling</u>

It is recommended to cause as little stress as possible through catching and handling individuals. This can be achieved most effectively by encouraging the animal in to its nest box. It is then possible to block off the entrance and slide the box into a bag, into which the animal can then be released. If this is not possible you can restrain an animal by its head with your hand in an animal bag, this can then be inverted over the animal and tied up. Individuals can then be presented for treatment in this manner.

<u>References</u>

Speldewinde P, Morris K. 1996 Djoongari Recovery Team Annual Report CALM.

Lambert C, Power V. 1997 Husbandry Procedures Shark Bay Mouse or Djoongari (*Pseudomys praeconis*) Native Species Breeding Program.

Watts C.H.S. Spencer L. 1978 Note on the reproduction of the Shark Bay Mouse (*Pseudomys praeconis)* in captivity. Institute of Medical and Veterinary Science, Adelaide, South Australia.

Watts C.H.S. ? Australian hydromyine rodents: maintenance of captive colonies. Laboratory Animal Services, Institute of Medical and Veterinary Science, Adelaide.

Speldwinde P. Morris K. and Orell P. 1996 Djoogari (Shark Bay Mouse) Recovery Plan 1992-2001. CALM.

The Southern Dibbler (*Parantechinus apicalis*) at the Perth Zoo

Cathy Lambert - 31st October 1998

The Dibbler

The Southern Dibbler (*Parantechinus apicalis*) is a small carnivorous marsupial, belonging to the family Dasyuridae. Although predominantly insectivorous, they have also been known to consume small lizards and birds (chicks), rodents, and small native marsupials such as dunnarts. They will also eat fruits from some native plants, and lick nectar from the flowers. Their backs are covered with brownish-grey fur freckled with white, and their undersides are greyish-white tinged with yellow. They are easily distinguished by a striking white ring around each eye, and by their tapering hairy tail. They are extremely quick, agile animals. Males weigh between 60 and 100g, while females are smaller, and weigh between 40 and 75g. Their head/body length is approximately 140-145mm. Dibblers breed once a year, (March/April) and can carry up to 8 young in a shallow pouch. The young remain dependent for 3-4 months, and become sexually mature at 10-11 months of age. Data from breeding animals at the Perth Zoo suggests that the gestation period is 41 to 47 days.

Conservation Status and History

Sub-fossil and historical records indicate that the Dibbler was once distributed from the coastal regions of Shark Bay on WA's west coast, to the Eyre Peninsula in South Australia. However, like many of Australia's animals, it has suffered a huge range contraction. In fact, between 1904 and 1966 no Dibblers could be found at all, and they were considered "presumed extinct". Fortunately they were "rediscovered" in 1967 near Albany on WA's south coast, followed by another discovery on 2 small islands off Jurien Bay, approximately 200km north of Perth. Genetic analysis of the 'island' versus the 'mainland' populations is being conducted to discover if they may be separate sub-species. The results will have implications for recovery actions required to save the Dibbler. The 'island' animals are smaller than 'mainland' ones, but this may not necessarily be a genetic factor. The Dibbler is now classified as "endangered".

Perth Zoo's Role in Dibbler Conservation

The Perth Zoo is a member of the Dibbler Recovery Team, and is involved in contributing to some of the key objectives outlined in CALM's Interim Recovery Plan for the species. Those objectives the zoo aims to contribute to are:-

1. Breeding captive animals for the establishment of a new island population from their progeny.
2. Contributing information about the Dibbler (in particular their reproductive biology), which will assist in the writing of a full Recovery Plan.

In collaboration with CALM, University of WA, and the Marsupial Cooperative Research Centre, the Perth Zoo is conducting a comprehensive research programme for the Dibbler. In late March 1997, 4 male and 4 female Dibblers from the 'island' populations were brought into the zoo by CALM, for the establishment of a research/breeding colony.

Captive Husbandry

Although Dibblers have been maintained in captivity for several years at other institutions in the past, no young have ever been produced. This was therefore going to be one of our major challenges.
Every effort is made to house and feed the Dibblers in a manner which simulates their wild conditions.

Diet

* Water is supplied *ad lib.*
* A morning feed of live native wood-roaches, crickets, mealworms, termites or moths is given. Most of this is scatter fed to offer enrichment and encourage natural hunting behaviour.
* An evening feed of various combinations of chopped dead baby rats, chicken, kangaroo meat, egg, cat kibble, small carnivore mix, sultanas and figs is given, with SF40 (vitamin preparation) being mixed with the meat portion.
* The proportion of invertebrates in the diet approximates what they would take in the wild, although in the non-breeding season this is reduced to a maintenance level.
* When seasonally available, fruits from native bushes known to be in the Dibblers' wild diet, and nectar-filled blossoms are fed in.

Housing

* Dibblers are maintained in a temperature-controlled building under the normal daylight conditions of Perth (windows and skylights).
* Each Dibbler is housed singly in a 4ft glass aquarium, with a sand substrate covered by a deep layer of leaf litter. Fresh *Acacia* branches are added to provide cover and enrichment.
* A nest-box filled with sea-grass is provided.

Captive Breeding

In the 2 seasons Dibblers have been at the Perth Zoo, we have had 44 animals born and raised to maturity. 19 were produced from the original island 'founder' animals in the 1997 season, most of which were probably conceived in the wild. The other 25 were second generation zoo born animals in 1998, making it the first time Dibblers had been bred in captivity. While this was terrific news, there was a down side. We actually had more than these 44 animals born at the zoo, however, there were some episodes where the mothers ate their young while still in the pouch. Unfortunately, as with any new species being bred for the first time, there are often "teething problems' in refining the correct husbandry methods. We have developed a number of strategies we hope will prevent this from occurring again in subsequent seasons.

Urine and faecal samples are collected from the breeding group in the lead up to the breeding season. Cells from the urine are easily extracted and examined microscopically, for signs of sperm in the males, and oestrus in the females. The cells in the females' urine are epithelial cells shed from the lining of the reproductive tract, and the different developmental stages of them allow us to determine what stage of the oestrus cycle the female is in. This information is important if we are to optimise our chances of reproductive success, allowing us to only pair animals that are both in full breeding condition.

Preparation for Release

In October 1998, the first release into the wild of zoo born animals occurred. 26 Dibblers of mixed ages were handed over to CALM for release to Escape Island off Jurien Bay. The animals were permitted to increase in weight prior to release, so they would be better able to cope with the stresses involved, and the possible early difficulty of finding food upon release from captivity. They were also fed a more varied diet of live invertebrate food, so they would recognise a greater array of prey items.

References and further reading

Fuller, P.J. and Burbidge, A.A. 1987. Discovery of the Dibbler, *Parantechinus apicalis*, on islands at Jurien Bay. *The Western Australian Naturalist* . **16:** 177-81.

Morcombe, M.K. 1967. The rediscovery after 83 years of the Dibbler *Antechinus apicalis* (Marsupialia, Dasyuridae). *The Western Australian Naturalist.* **10(5):** 103-11.

Start, A.N. 1998. - for the Dibbler Recovery Team. June 17 draft of Dibbler, *Parantechinus apicalis*, Interim Recovery Plan 1998-2000. WA Department of Conservation and Land Management - unpublished.

Strahan, R. 1995. (Ed.) *The Mammals of Australia.* Reed Books, Chatswood, NSW.

Woolley, P,A. 1971. Observations on the reproductive biology of the Dibbler, *Parantechinus apicalis* (Marsupialia: Dasyuridae). *Journal of the Royal Society of Western Australia.* **54:** 99-102.

Woolley, P.A. 1991. Reproductive pattern of captive Boullanger Island Dibblers, *Parantechinus apicalis* (Marsupialia: Dasyuridae). *Wildlife Research* . **18:** 157-63.

Greater Stick- nest Rat

Leporillus conditor
Native Species Breeding Program
Perth Zoo
Written by Andrew Lynch

Aboriginal people of the Wongkanguru group most commonly refered to this member of the order Rodentia, as the Wopilkara. It is one of two rodent species currently being kept as part of Perth Zoo's Native Species Breeding Program (NSBP). All species currently part of the NSBP section at Perth Zoo are undergoing a number of research projects in the attempt to learn more and refine the skills needed for captive breeding and management programs. This paper will cover the existing husbandry and management techniques for the Wopilkara.

In December 1996, five pairs were acquired from the Monarto Zoo in South Australia in order to establish a breeding colony at Perth Zoo. The current population is twenty-two animals.

Feeding Routine

The best time to observe the Wopilkara is early in the morning or late afternoon. Consequently, these are the best times to feed so observations can be made without having to catch the animals and place unecessary stress upon them. Each animal is fed a standard quantity of canary seed and mouse cubes (36g and 10g respectively). Some of our animals are suffering from cataracts. The cause/s of cataracts still need to be investigated further, but information suggests that it is most likely a genetic problem or one associated with dietry deficiancies. The diet fed at Perth Zoo is a good approximation of the Wopilkara wild diet however, there may be a deficiency in vitamin E, vitamin C and vitamin B.

The vitamin B is needed in greater amounts when the Wopilkara are under any form of stress. The deficiency of vitamin C could be explained by the omission of the fruits and berries found in the wild that they do not receive at Perth Zoo. To remedy these deficiencies the Wopilkara receive macropod cubes that contain vitamin E supplements (ie 50: 50 of mouse cubes to macropod cubes - of the 10g). Powdered vitamin B and vitamin C are lightly sprinkled over some carrot every second day. The introduction of these vitamin supplements has effected the frequency and severity of the cataracts. It is too early to determine whether the problem has been solved.

In conjunction with the basic seed and cube diet we also incorporate carrot and a variety of salt bushes into the diet. The Wopilkara receive carrot one day and salt bushes the next on a rotational basis. A variety of salt bushes have been planted in the grounds at Perth Zoo specifically for the needs of the Wopilkara. There are many species of coastal plants eaten by the Wopilkara. The species grown at

Perth Zoo are ones that are able to handle or adjust to the climatic conditions of the region. They are as follows: *Tetragonia decumbens* Coastal Sea Spinach
Atriplex sp. Coastal Saltbush
Atriplex isatidea Saltbush
Rhagodia baccata Coastal Bluebush
Carpobrotus virescens Pigface
Threlkeldia diffusa Ice Plant

The Wopilkara also recieves *Acacia* spp. on a regular basis. This is primarily for the animals to construct their nests with. Most *Acacia* sp are accepted by the Wopilkara, however there is a clear preferance for species that have a high water content (ie large fleshy leaves). Acacia is supplied on a regular basis, usually every one or two days. Generally the Acacia needs to be fresh or the animals will not utilise it. Other plant species are utilised in the wild, depending on the environment, for nest construction.

The Wopilkara is predominantly a herbivour however the remains of fleas, mites, grasshoppers and other invertebrates have been found in the stools of wild caught animals. Seasonal rainfall and fodder species provide the rats with sufficient water, in the wild. In captivity, water is supplied and cleaned on a daily basis.

Hygiene

As with most captive animals hygiene is extremely important for the well being of the Wopilkara. Cleaning of cages and any surfaces (ie nest boxes etc) should takes place every 2-3 days, particularly when more than one animal share accomodations.

Enclosures

In the wild the Wopilkara is a social animal, with as many as twenty animals sharing the same nest. The Wopilkara however, can be extremely aggressive towards each other, with females being the dominant animals. Therefore, most of our animals are housed in seperate enclosures except when breeding is occuring. Family groups will live in relative harmony and we have a few enclosures with two animals (sisters) in them. Once family groups have been separated, it becomes very difficult to reintroduce animals, due to aggression over territory.

All enclosure are provided with nest boxes, which are situated on the side of their nests. The Wopilkara will often construct it's nest around the nest box. Sea grass is added to nest boxes for warmth.

Breeding

The breeding of the Wopilkara has, for the moment, been put on hold. More investigation into the causes of cataracts needs to occur. If there is a genetic factor or cause then the long term viability of our animals need to be assessed.

Cataracts have been found in wild caught animals and there is evidence this is a genetic trait. Wild animals with cataracts probably fall victim to predation.

Release

There has not been a release of Wopilkara from Perth Zoo to date, for the same reasons mentioned under breeding. Salutation Island (Shark-Bay) is the proposed site for the first release. This will be the responsibility of CALM officers.

The Power of

'New' Genetics

and their potential uses for conservation questions

in Western Australia

Peter Spencer

PERTH ZOO
Western Australia

AIMS

- Maintain Genetic Diversity
- Humankind has a role
- Impossible to preserve
  - Selection
  - Large population size
  - Mutations cause change

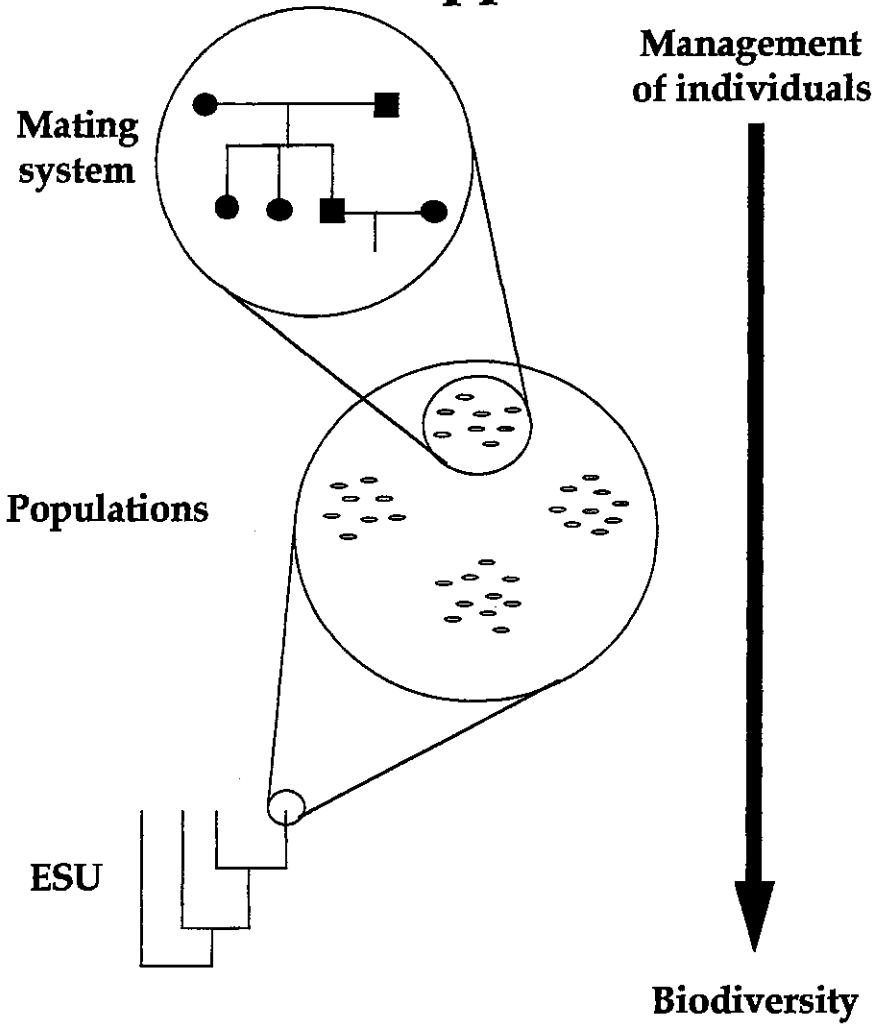
An Outline of the role of Conservation Genetics

- Aims of Conservation Genetics
- Commonly used terms
- Conservation Applications
- Tools
- Most appropriate methods
- Uses of molecular tools
- Population genetics - the changes
- Examples from Western Australia
- Conclusions

Some Common Terms used in Genetics & Conservation

- Genetic variation ("heterozygosity")
- Inbreeding
- Genetic drift
- Bottlenecks
- Selection
- Fragmentation
- The "Extinction Vortex"
- Genetic Markers
- Environmental and demographic stochasticity

Conservation Applications



Uses

- Genetic variation
  - Number of allele's
  - Observed heterozygosity
  - Expected heterozygosity
- Allele frequency between populations
  - Genetic subdivision
- Effective population size
- Mating system
  - Mating system
  - Outbreeding
  - Relatedness
  - Sexual selection
- Taxonomic questions

Some Methods
(and how they are used)

Allozymes

- Technique looking at variation at protein loci
- Well established for 30 years
- Not much variability (in mammals)

Microsatellites and mtDNA

- Most exciting technique
- Enormous potential
- Benign sampling
- Probability of excluding false parentage
- Very powerful technique
  - » tissue, blood, hair, urine
  - » Preserved sample: EtOH & formaldehyde
  - » Mucosal lining of faecal pellets, mosquito blood meals
  - » Museum specimens
- mtDNA

Three Examples of the application of Conservation Genetics

- **Brushtailed Phascogale**
  (*Phascogale tapotafata*)

  - a question of taxonomy

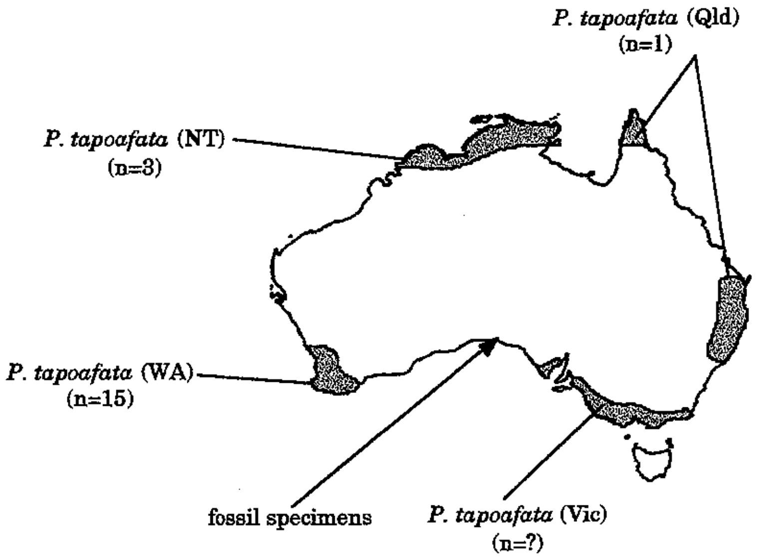
- **Mala**
  (*Lagorchestes hirsutus*)

  - How much genetic variation do populations of *L. hirsutus* retain ?
  - How different are populations of *L. hirsutus* ?

- **Rock-wallaby**
  (*Petrogale assimilis*)

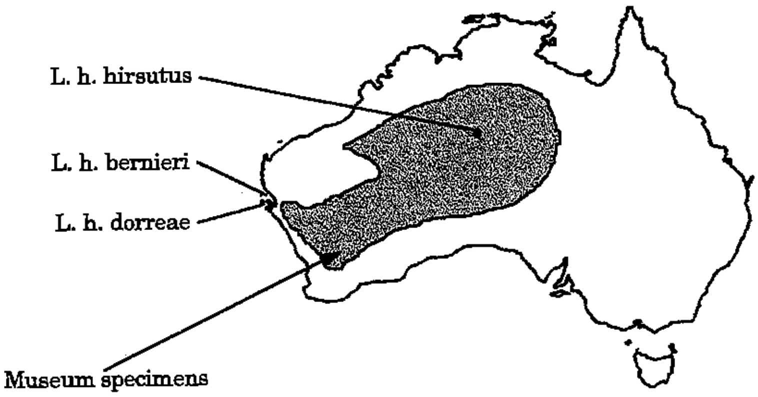
  - determine the mating system

Example I
Phascogale tapoatafa



- Originally - large distribution
- Five geographical areas (subspecies?)
- Presently have two species ('Southern' and 'Northern')
- some evidence from morphology that there are differences
- Molecular taxonomy never carried out
- Large differences found
- The different groups are now considered to be dfferent species

Example I
Lagorchestes hirsutus



- Once common and widespread
- Three subspecies
- Relationships between groups important
- Introductions - inevitable
- Island populations - large fluctuations in population size
- morphological data also important
- mtDNA - " The Taxonomic Tool of Choice "
- 10 animals from Bernier and Dorre Island
- existence of museum specimens in the UK

How different are populations of *L. hirsutus* ?

Average % sequence difference - Cytochrome *b*

	L. conspicillatus	*L. hirsutus*		
		BI	**DI**	**Captive**
L. conspicillatus	-	13.51	13.50	13.58
L. hirsutus				
Bernier Isl. (BI)		0.55	0.78	1.50
Dorre Isl. (DI)			0.63	1.60
Captive (TD)				1.12

- **Genetic distances similar amongst all populations**

Genetic distance amongst island and mainland populations of RHW

	Captive	Dorre Is.	Bernier Is.
Captive	-		
Dorre Is.	0.83	-	
Bernier Is.	0.90	0.80	-

- **Island populations represent a genetic subset of the mainland**

- **This is not uncommon for islands and is less exaggerated for *L. hirsutus***

How much genetic variation do populations of *L. hirsutus* retain ?

Microsatellites

- 43 alleles detected (all populations)
- Captive colonies retain high levels of genetic variation
- Most alleles (77%) found in the captive colonies
- Islands — Bernier Island 29% (n=14.1 animals)
  Dorre Island 22% (n=7.9 animals)
- Both islands show low levels of genetic variation
- Both island populations are highly inbred.
  inbreeding coefficient (F_e) ~ 0.6 for both islands
  (Fe = 0.0 = outbred; Fe = 1.0 = fully inbred)
- 22 alleles found in the island populations (9 shared b/w)
- Consequently, each island had some unique alleles
  (3 Dorre; 6 Bernier)

These can serve as useful "genetic tags" and could be used to identify origins of individuals

Summary of microsatellite data from three *L. hirsutus* populations.

	Mean sample size	# loci	% loci polymorphic	Mean # alleles per locus	H_e	% of unique alleles
Captive	13.3 + 0.7	8	100	4.1 + 0.6	0.62 + 0.07	0.64
Dorre Is.	7.9 + 0.1	8	62.5	1.9 + 0.3	0.22 + 0.09	0.20
Bernier Is.	14.1 + 0.9	8	75.0	2.0 + 0.3	0.29 + 0.08	0.38

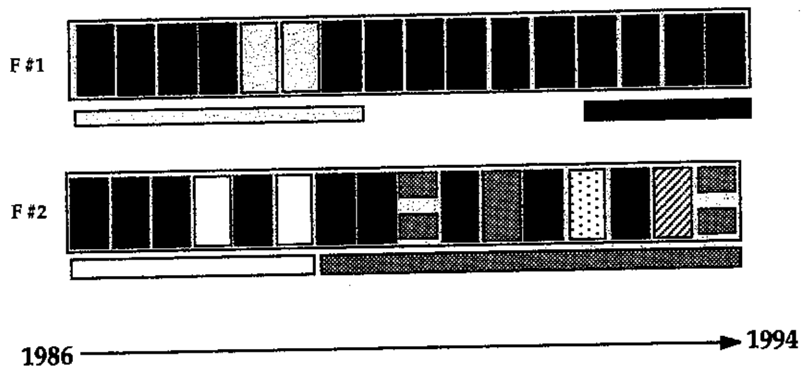
RECOMMENDATIONS

ESU's	*Populations isolated historically*
MU's	*Currently isolated, but historically connected*

For *Lagorchestes hirsutus*..........

- **Current data does not support recognition of ESU's**
- **But justification for MU's**
- **Both microsatellite and mtDNA data provide little justification for retaining sub-species status**
- **The remnant mainland RHW population is an absolute treasure**
- **Most important priority are the mainland population(s) - as they are the ones with most variability**
- **However, to prevent loss of genetic variability it is important that the current captive populations be rapidly increased in size (preferably 1000's)**

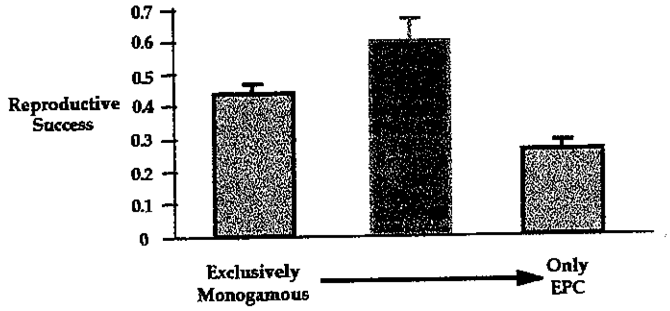
What do you do if your partner doesn't perform?



- Multiple mating system
- Some females remain faithful, but others do not!
- On average 33% of young are fathered by extra-pair males

Mating system	Males	Females
Monogamy	✓	✓
Polygamy	✓	NO
Promiscuous	✓	✓

- Females who are monogamous have a higher level of reproductive success
- Females who seek EPC's have a lower reproductive success



Conclusions

- Conservation genetics has a lot to offer
- Huge amount of information can be found out about a species through conservation genetics
- Range from basic understanding of
  - levels of genetic variation
  - mating systems
  - taxonomic questions
- New techniques
- Perth Zoo is taking an active role

Social Attitudes, Politics, Philosophy and Conservation of Marsupials in Australia

Presented by

Professor Des Cooper

1.

POLITICS - THE PLAYERS

State Wildlife Authorities

Australian Nature Conservation Agency (ANCA)

RSPCA

ANZFAAS

Australian Conservation Foundation

Forestry Industry

Tourism Industry

Universities

Scientists

Veterinarians

Philosophers

CSIRO

WIRES

Cooperative Research Centres (CRC)

The Media in Australia

The Media Overseas

2.

ATTITUDES ("PHILOSOPHY")

1. Vermin (especially NZ - but increasingly uncommon in Australia, even in rural areas).
2. National "icon", national symbol - tourism.
3. National treasure - conservationists.
4. Intrinsic scientific interest - especially the contrast with eutherians - scientists.
5. Concern for preservation of species - scientists.
6. Care for individual animals - WIRES-type groups; RSPCA; WIRES (but note human ethics and nature dilemma).
7. Sustainable resource - Grigg proposal.
8. Good tucker - gourmets.
9. Aesthetic - film makers, photographers, artists.
10. National identity - most Australians. (Coat of Arms; even the boxing kangaroo.)

3.

PHILOSOPHY AND POLITICS - SOME PRELIMINARY OBSERVATIONS

1. Any coherent conservation philosophy for Australia must incorporate marsupials.
2. *"The Future Eaters"* - Flannery.
3. Level of public understanding - not high.
4. Northern Hemisphere bias
   - Humans, rats, mice are "normal"
   - Marsupials inferior, on way out.
   - Marsupials are "funny".
5. Problem of language

   "The Kangaroo" - 5 species
   "The Wallaby" - 45 species
   (Do we say "the ruminant"?)

   Marsupial "cat"
   "mouse"
   "tiger"

   American Opossum v. Brushtail Possum

   Should we use Aboriginal names to aid differentiation?
   (Note story of New Guinea bird species.)
6. Are we part of nature? Should we use "natural" to exclude humans and their activities?

CHAPTER 7

CONSERVATION OF MARSUPIALS, ESPECIALLY MACROPODIDS - SOME ISSUES

PROFESSOR DES COOPER

1.

"RECENT" ENTRY OF EUTHERIAN MAMMALS INTO AUSTRALIA

5 MYR BP (?) — RODENTS

↓

RADIATION
Ω 100 ENDEMICS

4000 YR BP — DOG (DINGO)

100-200 YR BP

FOX
CAT
GOAT
WATER BUFFALO
RABBIT
MOUSE
BROWN RAT
BLACK RAT
CAMEL
HORSE
PIG
DEER SPP

SHEEP
CATTLE

HOMO SAPIENS
40,000 YR BP?

2.

CONSEQUENCES OF EUROPEAN OCCUPATION OF AUSTRALIA

INTRODUCTION OF EXOTICS
REDUCED FIRING OF FLORA
RANGELAND EXTENSION
FARMLANDS
LOSS OF FORESTS
INTRODUCTION OF WATER SOURCES

↓

SMALL MACROPODIDS ↓
LARGE MACROPODIDS ↑ (?)
LARGER CARNIVORES ↓
REDUCED HABITAT FOR SOME ARBOREAL MAMMALS

↓

SOME EXTINCTIONS
SOME THREATENED SPECIES
MANY RANGE REDUCTIONS

3.

APPROACHES TO CONSERVATION OF AUSTRALIAN MARSUPIALS

IS THE CATALOGUE OF SPECIES COMPLETE?

REMOVAL OF EXOTICS THROUGH BIOLOGICAL CONTROL, ESPECIALLY FOXES AND RABBITS

CONTROL OF DISEASE
- TOXOPLASMA
- HERPES VIRUS

ROLE OF ZOOS

GENETIC MONITORING
- KOALA
- EASTERN BARRED BANDICOOT
- BRUSH TAILED BETTONG
- PARMA WALLABY

RE-INTRODUCTION (?)

4.

ROLE OF HYBRIDS IN CONSERVATION BIOLOGY

INTER-SPECIES HYBRIDS STERILE
INTER-RACIAL HYBRIDS FERTILE

TYPOLOGICAL (AS OPPOSED TO POPULATION) CONCEPT OF A SPECIES USED BY LEGISLATORS, WILD LIFE AUTHORITIES DOES NOT PROTECT INTER-RACIAL HYBRIDS.

WHY NOT?

IN SOME CASES, FERTILE HYBRIDS ARE FORMED IN CAPTIVITY BETWEEN POPULATIONS WHICH ARE REPRODUCTIVELY ISOLATED IN THE WILD.

HOWEVER, THERE IS A FAILURE TO RECOGNISE THAT POPULATIONS WHICH HAVE BEEN REDUCED IN SIZE HAVE NECESSARILY UNDERGONE GENETIC CHANGE.

HYBRIDISATION WITH ANOTHER SUB-SPECIES MAY BE THE ONLY WAY TO SAVE THE GENE POOL.

5.

AIMS OF CONSERVATION GENETICS

TO CHARACTERISE AND MANAGE THE GENE POOL, TO ENSURE THE SURVIVAL OF THE LINEAGE TO WHICH THE CONTEMPORARY SPECIES BELONGS.

HOMQ SAPIENS AS THE STEWARD OF PLANET EARTH.

THE EYES OF THE BLIND WATCHMAKER ARE OPENED.

THE IMPOSSIBILITY OF PRESERVATION:
SELECTION, FINITE POPULATION SIZE AND MUTATION MAKE EVOLUTION INESCAPABLE.

IN AUSTRALIA, A UNIQUE SITUATION:
A REAL POSSIBILITY OF CHECKING THE DEPLETION OF THE FAUNA CAUSED BY HUMAN ACTIVITY.

6.

ACTUAL AND POTENTIAL TOOLS OF CONSERVATION GENETICS

1. KARYOTYPING
2. ALLOZYME VARIATION
3. MOLECULAR
   - RFLP
   - SEQUENCING
   - MICROSATELLITES
   - RAPIDS
   - MITOCHONDRIAL
4. POPULATION GENETICS THEORY
5. SELECTIVE BREEDING FOR
   PREDATOR AVOIDANCE
   DISEASE RESISTANCE

(NOTE GENETIC MODIFICATION OF MICROORGANISMS TO CONTROL INTRODUCED PREDATORS.)

7.

GENETIC TYPING METHODS

	TECHNIQUE					
Question Addressed	Karyotypes	Allozymes	mtDNA RFLPs	mtDNA Sequencing	Single Nuclear Probes	Multilocus Probes
Within Population Variation	•	•	••	•••	•••	••••
Between Sub Species	•	••	•••	•••	•••	••••
Between Species	••	•••	••••	••••	••••	•••••
Hybrid Recognition	••	•••	-	-	••••	•••••
Genetic Distance Measures	•	••	•	•	••	•
Parentage Identification	•	••	•	•	••	•••
Cost	••	•	••	•••	•••	••
Availability of comparative marsupial data	•••	•••	••	•	••	••

USES OF MICROSATELLITE GENE MARKERS

Because there are so many alleles at each locus, they can be used to:

1. Identify parents and offspring, in both wild and captive populations.

2. Identify individual animals.

3. Identify species of a particular sample.

4. Estimate intra-population variability i.e. identify bottlenecks, inbreeding.

5. Establish degree of inter-population variation.

6. For forensic purposes (see 2, 3 above).

SOME USES OF GENETIC TYPING IN CONSERVATION BIOLOGY

<u>GENERAL</u>

1. DEFINE LEVELS OF GENETIC VARIABILITY WITHIN POPULATIONS.

2. DEFINE GENETIC DISTANCES BETWEEN POPULATIONS.

<u>AUSTRALIAN</u>

1. DEFINE RELATIONSHIP BETWEEN ISLAND AND MAINLAND POPULATIONS.

2. DEFINE RELATIONSHIPS BETWEEN ELEMENTS OF RESURGING POPULATIONS E.G. IN WESTERN AUSTRALIAN AREAS AFTER REMOVAL OF FOXES BY BAITING.

3. DEFINE HYBRID ZONES.

AUSTRALIAN MARSUPIALS ON ISLANDS

Dasyurus maculatus •
viverrinus •◊
hallucatus

Sarcophilus harrisii •

Antechinus minimus
swainsonii •

Pseudantechinus minimulus ◊Δ

Parantechinus apicalis Δ

Sminthopsis leucopus
aitkeni Δ
virginiae Δ

Planigale maculata

Isoodon obesulus Δ
auratus Δ

Perameles gunii Δ
bougainville ◊Δ

Phascolarctos cinereus Δ

Vombatus ursinus

Pseudocheirus peregrinus

Petropseudes dahli

Petaurus breviceps

Trichosurus vulpecula Δ
arnhemensis Δ
caninus Δ

Cercartetus nanus •
lepidus Δ
concinnus

Potorous tridactylus Δ

Bettongia gaimardi •◊Δ
lesueur ◊Δ

Lagostrophus fasciatus ◊Δ
conspicillatus Δ
hirsutus Δ

Petrogale lateralis Δ
inornata
rothschildi
burbidgei
concinna Δ
persephone Δ
assimilis
brachyotis

Thylogale billardierii ◊

Macropus eugenii Δ
rufogriseus
giganteus •
fuliginosus
robustus
agilis

Setonix brachyurus Δ

Wallabia bicolor

• = Only island they occur on is Tasmania.

◊ = Marsupials that <u>only</u> occur on islands.

Δ = Island populations of threatened marsupials.

Strahan (1983) and Kennedy (1992).

POSSIBLE GENETIC DIFFERENCES ARISING THROUGH RECENT (~ 10,000 BP) ISOLATION ON CONTINENTAL ISLANDS

1. ACCELERATED GENE FREQUENCY CHANGE THROUGH SMALL POPULATION SIZE ("DRIFT").

2. LOSS OF GENETIC VARIABILITY.

3. LACK OF ADAPTATION TO SUBSEQUENTLY INTRODUCED PREDATORS.

   DINGO 4,000 BP
   FOX
   CAT

4. ALTERATIONS TO DIGESTIVE, ELECTROLYTE FUNCTIONS.

5. SIZE.

6. LACK OF ADAPTATION TO PATHOGENS, ESPECIALLY THOSE INTRODUCED BY EUROPEANS (TOXOPLASMOSIS).

MARSUPIALS INTRODUCED AND ESTABLISHED IN NEW ZEALAND - CONSERVATION THROUGH TRANSLOCATION

SPECIES	CONSERVATION ISSUE
BRUSH-TAILED ROCK WALLABY	THREATENED IN AUSTRALIA
TAMMAR	EXTINCT SOUTH AUSTRALIAN POPULATION (?)
PARMA	RE-ESTABLISHED IN AUSTRALIAN ZOOS
POSSUM	A DISASTROUS INTRODUCTION
BENNETT'S WALLABY	NONE
SWAMP WALLABY	NONE

Paper for the Marsupial CRC / VBCRC Symposium
"Mammal Conservation in WA"
Perth Zoo, November 1998

TRANSLOCATION OF THREATENED FAUNA

Keith Morris
CALMScience
Department of Conservation and Land Management
Wildlife Research Centre
Woodvale WA 6065

keithm@calm.wa.gov.au

Summary

Translocations, particularly reintroductions, are an extremely useful wildlife management tool. Over the last 20 years many have been successfully implemented in WA and two species of mammal have now been removed from threatened fauna lists primarily because of successful reintroduction programs. Many other vertebrate species have also been successfully translocated, and translocations of threatened plants are now underway. Inappropriate or poorly planned translocations can also be detrimental to wildlife conservation objectives and in WA, IUCN guidelines have been adapted to ensure translocations are properly implemented.

Introduction

Translocation is the movement of living organisms from one area with free release in another. It is one of the most valuable tools for the management of natural ecosystems, particularly in the area of fauna recovery. But it can also be one of the most destuctive if used improperly or poorly planned. Three main types of translocation are recognised (IUCN 1987):

- **Introduction** is the intentional or accidental dispersal by human agency of a living organism outside its historically known range (e.g fox, cat, weeds).
- **Re-introduction** is the intentional movement of an organism into a part of its native range from which it has disappeared in historic times as a result of human activities or natural catastrophe (many examples, discussed later).
- **Re-stocking** is the movement of numbers of plants or animals of a species with the intention of building up the number of individuals of that species in an original habitat (e.g Chuditch to Lake Magenta).

WA is fortunate in that effective fox control programs can be implemented over large areas, and many species that have become extinct on the mainland survive on offshore islands. Thus we are able to control one of the primary causes of fauna (particularly mammal) declines and we have a source of fauna for translocations. In WA most translocations have involved threatened animals, however the technology is now available to use translocations to benefit threatened plants and this will be an area of increased activity over the next few years.

Why do we translocate?

Translocations occur for many reasons including:

- accidental introductions, e.g rats, house mice etc.
- rural development, e.g. crops and food crops, domestic stock.
- improvement of hunting or fishing, e.g. rabbits, foxes, pheasants, trout.
- ornamentation, e.g. *Watsonia*, doves, Koalas.
- maintenance of culture, e.g sparrows, starlings.
- commercial and education, e.g wildlife parks
- wildlife salvage, e.g. flooding of the Ord River, Quendas in the metro area, Ringtail Possums at Busselton.
- enhancement of biological diversity, either through improvement of single species conservation status, or reconstruction of floras and faunas.

When should we translocate, and when shouldn't we?

For conservation agencies, translocations should only occur to improve the conservation status of a species or community, or to lessen the impact of habitat destruction. They usually involve threatened species, but this is not always so. They may involve more common species to reconstruct the flora and fauna of an area, or to preserve genetic variability.

Introductions should only be considered if there are clear benefits to the conservation of the species and reintroduction options are not available. It also needs to be clear that there will be no detrimental impact of the introduced organism on the existing biota. Examples of introductions with conservation benefit are the marooning of the Shark Bay Mouse *Pseudomys fieldi* on Doole Island in Exmouth Gulf, the Greater Stick -nest Rat *Leporillus conditor* on Salutation Island, Shark Bay, and the transfer of Mala *Lagorchestes hirsutus* to Trimouille Island.

Re-introductions are the usual type of translocation undertaken by CALM for conservation purposes and there are many examples of these (Table 1). They should only be undertaken using the same genetic stock as originally present, if this is possible. The eradication or control of the original cause of extinction (e.g exotic predators) is essential before any translocation occurs, and the natural habitat requirements of the species must be known and met at the translocation site.

Re-stockings are usually undertaken to improve the genetic composition of the existing population. Therefore they should only use the same genetic stock (e.g same subspecies) as is already present.

Species	Date	Moved from	Moved to	Translocation type	Successful ?
Banded Hare Wallaby	1974	Dorre Is.	Dirk Hartog Is.	reintroduction	no
Rothschild's RW	1981	Enderby Is.	West Lewis Is.	introduction	yes
Numbat	1985	Dryandra	Boyagin	reintroduction	yes
	1986	Dryandra	Karroun Hill	reintroduction	yes
	1991	Dryandra	Tutanning	reintroduction	yes
	1992	Dryandra / Perth Zoo	Batalling	reintroduction	yes
	1995	Dryandra	Dragon Rocks	reintroduction	yes
	1996	Dryandra	Hills Forest	reintroduction	??
Chuditch	1992	Perth Zoo	Julimar	reintroduction	yes
	1996	Perth Zoo	Lake Magenta	restocking	yes
	1998	Perth Zoo	Cape Arid	reintroduction	?
Boodie	1992	Dorre Is.	Heirisson Prong	reintroduction	yes
	1993	Barrow Is.	Boodie Is.	reintroduction	yes
Woylie	1981	Perup	Batalling	reintroduction	yes
	1990	Dryandra	Boyagin	reintroduction	yes
	1994-5	Dryandra	Nth Jarrah	reintroduction	yes
	1995	Dryandra	Julimar	reintroduction	yes
	1996	Dryandra	Lake Magenta	reintroduction	yes
	1997	Dryandra / Batalling	Peron	reintroduction	?
Tammar Wallaby	1994	Perup	Batalling	reintroduction	yes
Ringtail Possum	1991	Busselton	Leschenault	reintroduction	yes
	1994	Busselton	Yalgorup	reintroduction	yes
	1996	Busselton	Lane-poole	reintroduction	yes
Quenda	1994	Swan Coastal P	Julimar	reintroduction	no
	1994	Mt Barker	Dongolocking	reintroduction	yes
Djoongari (Shark Bay Mouse)	1993	Bernier Is / Perth Zoo	Doole Is.	Introduction / restocking	yes
	1993	Bernier Is.	Heirisson Prong	reintroduction	no
Thevenard Island Mouse	1996	Thevenard Is.	Serrurier Is.	introduction	yes
Wopilkara (Greater SNR)	1991	Monarto (captive colony)	Salutation Is.	introduction	yes
Noisy Scrub-bird	1983	TP Bay	Mt Manypeaks	reintroduction	yes
	1993	TP Bay	Bald Is.	introduction	yes
	1997	TP Bay	Harvey	reintroduction	??
Malleefowl	1997/8	Northern Wheatbelt	Peron	reintroduction	yes
Western Swamp Tortoise	1996-98	Perth Zoo	Twin Swamps	reintroduction	yes?

Table 1. Some translocations undertaken in WA.

Translocation Proposals

CALM has adopted IUCN guidelines for the planning and implementation of translocations, and translocations will not be approved by the Director of Nature Conservation unless these are adhered to. A policy statement on translocation of threatened flora and fauna has been prepared by CALM (CALM 1995). The process by which translocations are assessed in WA is by means of completion of a Translocation Proposal. These are documents that are often referreed externally before being considered for approval. They cover:

- Summary
- Name and affiliation of the proponent
- Background on the species former range, current distribution, conservation status and biology.
- The translocation:
  - Details of the land status at translocation site.
  - Source of animals or plants. Why was this chosen?
  - If an Introduction, the impact on the existing biota needs to be assessed.
  - If an Introduction to an island, it must demonstrate that it will have no effect on possible other translocations to that island.
  - It a translocation from an island to mainland, it must demonstrate that the mainland taxon no longer exists.
  - Founder number and principles of conservation genetics.
  - Removal or control of the cause of previous extinction, e.g exotic predators.
  - Details of post release monitoring.
- Funding – source and long term commitment.
- Animal Ethics Committee approval – Code of Practice (NHMRC 1997).
- Endorsement by proponent's organisation.
- References.
- Attachments - normally translocation proposals will not be approved unless they form part of a Recovery Plan or Interim Recovery Plan.

Conclusions

WA is fortunate in that many threatened species still persist as relic populations. There are also several offshore islands which have remained exotic predator free. These factors combined with our ability to control foxes and to establish successful captive breeding programs enable us to use translocations as an effective fauna management tool. Successful translocations have been responsible for removing two species, the Woylie and Quenda, from the threatened fauna list and it is likely that several other species will be removed in the next few years. Once cat control becomes operational in the next 2-4 years, translocation programs will be expanded to include the semi-arid and arid parts of the State, and this will ensure that WA continues to lead Australia in fauna recovery programs.

References

CALM (1995). Translocation of Threatened Flora and Fauna. CALM Policy Statement No. 29.

NHMRC (1997). Australian code of practice for the care and use of animals for scientific purposes. National Health and Medical Research Council, Commonwealth of Australia September 1997.

IUCN (1987) The IUCN position statement on translocation of living organisms. Introductions, re-introductions and re-stocking. IUCN, Gland, Switzerland.

CHAPTER THIRTY-ONE

Reintroduction and the numbat recovery programme

J. A. FRIEND[1] and N. D. THOMAS[1]

Only two significant numbat populations, at Dryandra and Perup in the south-west of Western Australia, have survived the massive and widespread decline of the species. The numbat's recovery depends on the successful re-establishment of wild populations. A programme of reintroduction has been in progress since 1985, first by translocation from the wild to an area close to the source location and then to other areas within the numbat's former range. Fox control has been implemented at each site. The first reintroduction was to the eastern block (2 000 ha) of Boyagin Nature Reserve, 40 km north of Dryandra, where 35 numbats were released between 1985 and 1988. A population appears to have become established there, and numbats have now been recorded in the western block (3 000 ha), which is separated from the eastern block by 500 m of farmland. Since 1986, numbats have been translocated from the wild at Dryandra to three sites where regular baiting for foxes occurs. At a more arid site at Karroun Hill Nature Reserve (300 000 ha), rates of predation are high, due particularly to raptors and cats. The reintroductions to Tutanning Nature Reserve (2 000 ha) and the Batalling area (14 000 ha under fox control) are still in the early stages.

Key words: Numbats, Reintroduction, Fox Control, Predation, Feral Cats, Raptors.

INTRODUCTION

THE decline of the numbat *Myrmecobius fasciatus* since the introduction of European fauna and land management practices to Australia has been dramatic. One-hundred-and-fifty years ago, numbats occurred from the west coast across the southern half of the continent to western New South Wales. By the early 1980s, the species survived in only a handful of sites in bushland near the southwestern extremity of its former range (Friend 1990a). In the last 10 years, some of these small remnant populations have disappeared, and there are now only two significant surviving populations, both in Western Australia, near Narrogin at Dryandra and east of Manjimup at Perup (Fig. 1).

The biology of the numbat, a small mammal that attains an adult weight of 500–700 g, has been studied at Dryandra (Calaby 1960; Friend and Burrows 1983; Friend 1987, 1989) and at Perup (Christensen *et al.* 1984; Maisey and Bradbury 1985). Although most closely related to the carnivorous marsupials (family Dasyuridae), numbats have peculiar anatomical and behavioural traits that adapt them to a specialized diet of termites, which they extract from shallow galleries in the soil and from under dead wood on the ground. Up to four young are produced by each female in January or February after a gestation of 14 days and remain attached to her four nipples until July, when they are deposited in a nursery burrow. Weaning occurs in October, when food availability is high, and the juveniles disperse about six weeks later. Females breed in the first year, but males reach sexual maturity a year later. There is no evidence of pair fidelity, and males appear to take no part in the care of the young.

An investigation of the factors limiting numbat numbers and likely to have an impact on the conservation status of the species focused on the surviving population at Dryandra (Friend 1990a, b). This chapter outlines the role of reintroduction in the numbat recovery process and reports on the current status of the reintroduction programme.

DRYANDRA AND THE BEGINNINGS OF RECOVERY

For many years, the 28 000 ha of forest and woodland at Dryandra, 170 km south-east of Perth, has been known as the stronghold of the numbat (Fig. 2). Numbats were previously most numerous in the Western Australian wheatbelt, an area east of Perth now extensively cleared for cereal growing (Friend 1990a). Dryandra Woodland (28 000 ha) comprises 10 blocks of wooded land in the western part of the wheatbelt which was reserved for forestry purposes in the 1920s. Serventy (1954) drew attention to an increase in sightings of numbats and other marsupials at "Dryandra Forestry Settlement", and the definitive study of the numbat (Calaby 1960) was carried out at Dryandra in the mid-1950s because the animals were relatively abundant there. Apparently numbats could be reliably seen at Dryandra until the late 1970s, when the population declined dramatically (Friend 1987, 1990a). This event coincided with declines in other medium-sized native mammal species and

[1]Western Australian Wildlife Research Centre, Department of Conservation and Land Management, P.O. Box 51, Wanneroo, Western Australia, Australia 6065.
Pages 189–98 *in* REINTRODUCTION BIOLOGY OF AUSTRALIAN AND NEW ZEALAND FAUNA, ed by M. Serena. Surrey Beatty & Sons, Chipping Norton. 1994.

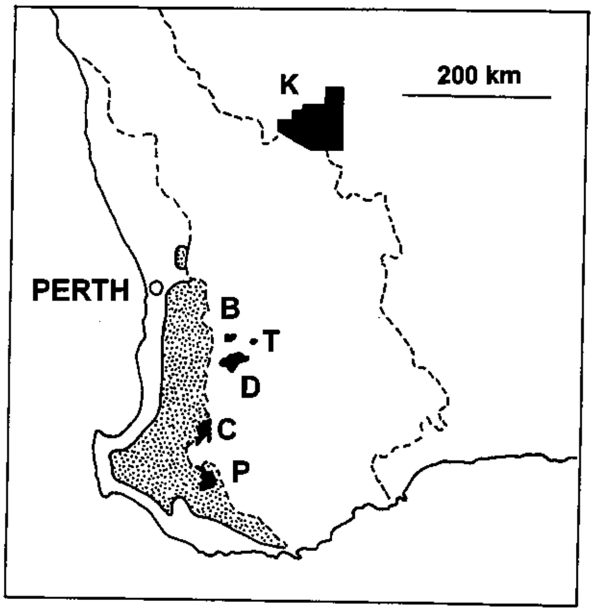


Fig. 1. The south-west of Western Australia showing places mentioned in the text. The main cereal growing area (the "wheatbelt") is bounded by dashed lines, and the stippled area shows the extent of State forest dominated by Jarrah *Eucalyptus marginata*. B — Boyagin Nature Reserve; T — Tutanning Nature Reserve; D — Dryandra Woodland; C — Batalling block; P — Perup Nature Reserve; K — Karroun Hill Nature Reserve.

an increase in numbers of the introduced Red Fox *Vulpes vulpes* in southwestern Western Australia (King *et al.* 1981). By monitoring numbat abundance in an area of 2 000 ha at Dryandra in which the number of foxes was reduced by poison baiting, as well as in an unbaited area, Friend (1990a) showed experimentally that these introduced predators were regulating the numbat population.

After the experiment, fox baiting continued at Dryandra and was extended in 1989 to encompass the two largest blocks (17 000 ha in total). The control programme uses baits consisting of 120 g (wet weight) of kangaroo meat injected with 4.5 mg of sodium monofluoroacetate (a highly toxic compound known as "1080") in aqueous solution. The meat baits are then dried to 40 per cent of original weight and stored at −20°C until needed (CALM 1990). Each month, baits are placed under bushes along perimeter roads and selected internal tracks at 100 m intervals. This procedure can be used with little risk to native animals because the vertebrate fauna of southwestern Australia have a characteristically high tolerance to 1080 (Twigg and King 1991).

The Dryandra population has continued to grow, despite the removal of 10–30 animals

Fig. 2. The lower valley slopes at Dryandra Woodland are dominated by Wandoo *Eucalyptus wandoo* with an open understorey composed mainly of Sandplain Poison *Gastrolobium microcarpum*, over a ground cover of low grasses and forbs. These areas support the highest densities of numbats. Wandoo trees are often hollowed out by the wood-eating termite *Coptotermes acinaciformis*, creating hollow logs when trees or branches fall.

annually since 1985 for reintroduction programmes. Figure 3 shows the rate at which numbats have been sighted each year during surveys from vehicles driven slowly along selected tracks (after the method of Calaby 1960). These data indicate that the numbat population at Dryandra has increased at least 50-fold since 1979, and that it is considerably larger now than it was after the documented increase of the mid-1950s. Some fox control was probably achieved in Western Australia in the 1950s and 1960s by secondary poisoning following the widespread use of 1080 to control rabbits. When myxomatosis became more effective as a rabbit control agent in the late 1960s following the introduction of a more efficient vector for the virus (the European rabbit flea), the use of 1080 declined and fox numbers increased (King *et al.* 1981). These events may explain both the increase in numbat numbers in the 1950s and the decrease in the 1970s.

The total number of numbats in the main block of Dryandra Woodland (13 000 ha) in November 1992 was calculated to be 800, by

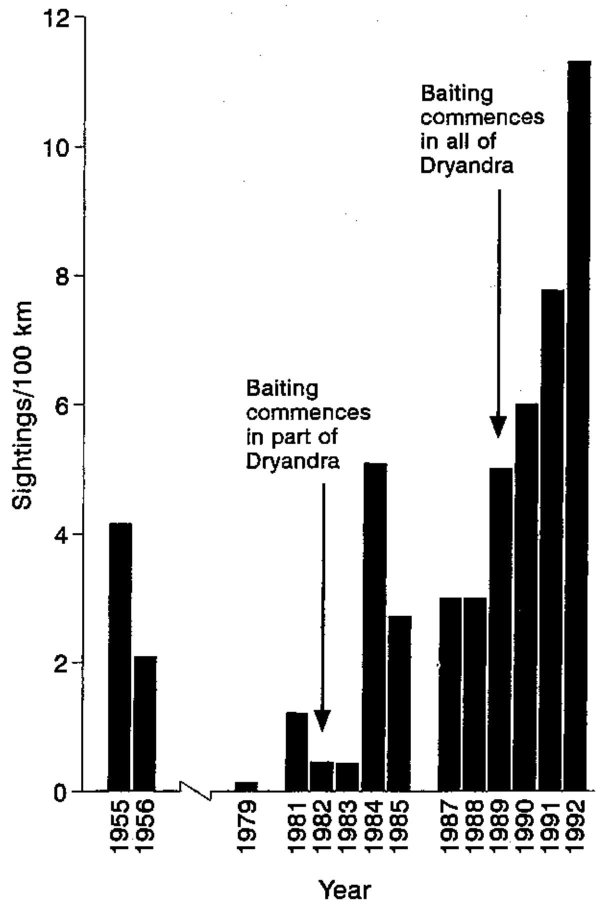


Fig. 3. Number of numbat sightings recorded per 100 km of driving surveys on roads in Dryandra Woodland. Distances driven were as follows: 1955, 385 km; 1956, 385 km; 1979, 718 km; 1981 413 km; 1982, 1 103 km; 1983, 704 km; 1984, 275 km; 1985, 590 km; 1987–88, 200 km per year; 1989–92, 400 km per year. Data for 1955–56 provided by J. Calaby.

extrapolating the results of a line transect survey (Friend, unpubl. data). Approximately 54 per cent of the animals caught in November and December 1992 were adults, so the population of the main block, where most of the Dryandra numbats are found, comprised about 430 adults and 370 young. A survey is now carried out in November each year before removing any animals for translocation, to confirm that population levels have been maintained.

REINTRODUCTION STRATEGY AND CHOICE OF SITES

As the survival of the numbat is now dependent on only two of its original populations, comprising a total of less than 1 500 animals (Friend 1994), establishing additional populations is essential to improve the conservation status of the species. In 1985, once the positive effect of fox control had been demonstrated, a trial reintroduction was planned. Translocation of wild animals from Dryandra was proposed to an area of similar rainfall, soils and vegetation, where numbats had recently become extinct. Fox control was to be implemented, in order to test the hypothesis that fox predation was the major factor preventing the persistence of numbat populations in such areas. If this translocation resulted in the establishment of a self-sustaining population, it would indicate that the quality of the habitat of the numbat at that site was still adequate, and that the previous extinction was due to fox predation, rather than factors affecting food supply or other habitat attributes. The next step to improve the conservation status of the species would be to conduct a series of monitored reintroductions under a regime of fox control to areas of different climate and vegetation within the numbat's former range.

Boyagin Nature Reserve (5 000 ha), 40 km north of Dryandra, satisfied the criteria for the first reintroduction site (Fig. 4). Numbats had been recorded there as recently as 1970, but had subsequently become extinct (Friend 1990a). The second site selected was Karroun Hill Nature Reserve (300 000 ha, annual rainfall about 250 mm), on the eastern edge of the Western Australian wheatbelt, where reintroduced populations could expand to the north and east into uncleared habitat on vacant Crown land and pastoral leases (Fig. 5). Numbats had previously occurred at Karroun Hill based on skeletal remains (Youngson and McKenzie 1977), and also nearby based on anecdotal accounts (Maddock 1987). A baiting regime using 1080 in meat baits was already in place around the perimeter of the reserve, to protect sheep on neighbouring farms and grazing leases from dingo predation.

Other reintroduction sites have been chosen on similar principles. Tutanning Nature Reserve (2 000 ha) approximates the minimum area able

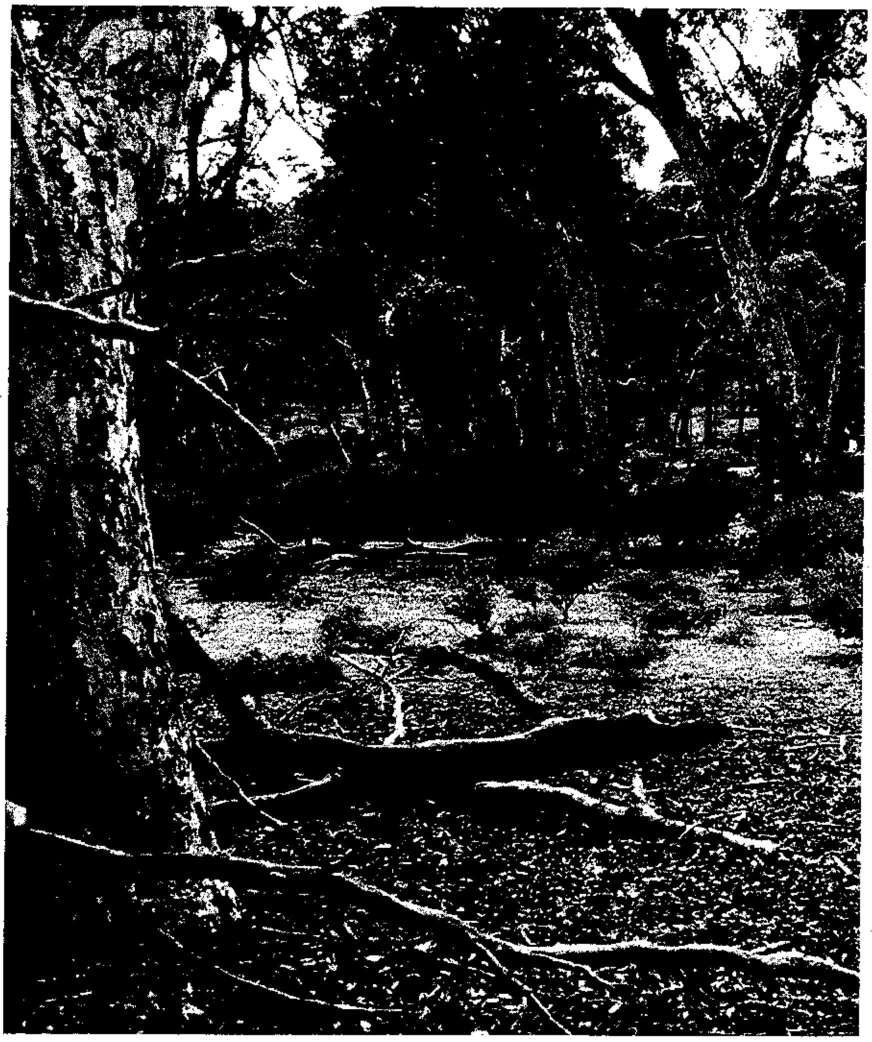


Fig. 4. Wandoo woodland in the valley where most numbats were released at Boyagin Nature Reserve. *Eucalyptus wandoo* is dominant over an open understorey of Box Poison *Gastrolobium parviflorum* with a ground cover of low grasses and forbs.

to support a population of 50 numbats (Friend 1987). Fox control has been part of its management since 1989, and had been carried out on the reserve for research purposes since 1984, resulting in a spectacular recovery of Brush-tailed Bettongs *Bettongia penicillata*, Tammar Wallabies *Macropus eugenii* and Common Brushtail Possums *Trichosurus vulpecula* (Kinnear 1990). Numbats were present at Tutanning until the late 1970s, and although searches in 1984 found a few diggings (Connell and Friend 1985) and a sighting was reported in 1986, more recent work (see below) indicated that the population was extinct by 1990. Batalling Block, an area of State forest east of the town of Collie dominated by Jarrah *Eucalyptus marginata*, was used successfully as a reintroduction site for Brush-tailed Bettongs in 1983 (Christensen and Leftwich, unpubl. data). Fox control has been carried out there since 1990 over an area of 6 000 ha, increased to 14 000 ha in 1992. Numbats were recorded near Muja, within 20 km of Batalling Block, as recently as 1982 (Connell and Friend 1985). In choosing future reintroduction sites in the numbat recovery programme, the entire range of habitat types previously occupied by the numbat will be considered, as well as those already used.

REINTRODUCTION TO BOYAGIN NATURE RESERVE

An adult male numbat was released as a pioneer into the eastern section (2 000 ha) of Boyagin Nature Reserve in early November 1985, followed by 16 animals (three adult and five subadult males; one adult and seven subadult females) in November and December (Fig. 6). This time of year, when young numbats are dispersing from their maternal home range, was chosen as the most suitable period for translocations. It is also the beginning of a 6–8-week period before the first births of the next year, when females can be translocated without risk to dependent young. Altogether, 35 numbats (eight adult and nine subadult males, eight adult

Fig. 5. Reintroduced numbats have occupied a range of vegetation types at Karroun Hill Nature Reserve. In the foreground a low woodland is dominated by several *Acacia* species, over a seasonal ground cover mainly composed of *Helichrysum lindleyi*. In the background, York Gum *Eucalyptus loxophleba* forms a higher canopy, and provides hollows both in fallen branches and in trunks which often lean to approach the horizontal.

and 10 subadult females) were released at Boyagin between November 1985 and March 1988 (Friend 1990a).

Numbats cannot be trapped by conventional methods, so the establishment of the population was monitored in three ways. Before release, all numbats were fitted with a radio-collar (single-stage SM-1 transmitter, AVM Instruments), allowing them to be located and recaptured at intervals so that their survival and breeding status could be determined. The degree to which the population occupied available habitat in the reserve was measured by surveys for fresh numbat diggings and scats near roads at 200 m intervals. Finally, sighting surveys from vehicles carried out according to the protocol used at Dryandra were implemented in 1992, when the population had risen to a sufficiently high level.

Results from monitoring the early stages of the reintroduction were reported in Friend (1990a). All translocated numbats established home ranges within six weeks (in some cases much sooner), and over 90 per cent of trans-located females produced young in the next breeding season. Six new animals were caught in 1986 and seven in 1987. Up to the end of 1989, 13 radio-collared numbats were known to have been taken by predators, judging from the damage to radio-collars and the state of remains. Four were presumed to have been taken by foxes, four by raptors and in five cases the species of predator could not be inferred from the evidence found.

Figure 7 shows the results of the survey for diggings and scats in November 1990. By this time, numbats had spread into all suitable habitat in the eastern section of the reserve. In October 1992, the search of the eastern block was limited to a series of monitoring sites, and a thorough search of the western block, where no numbats had been released, was carried out in November. These surveys indicated that all available habitat in the eastern block was still occupied, and that numbats were resident in several parts of the western block (Fig. 8).

The first vehicle-based sightings surveys at Boyagin were carried out in November 1992. The survey of the eastern block yielded seven sightings in 234 km (3.0 sightings/100 km). This compares well with sighting rates recorded at Dryandra since the introduction of fox control. No animals were sighted in 195 km of surveys in the western block, although a numbat was seen beside the road in November during non-survey driving, and there have been other sightings in the western block by Department of Conservation and Land Management staff in 1992 and 1993.

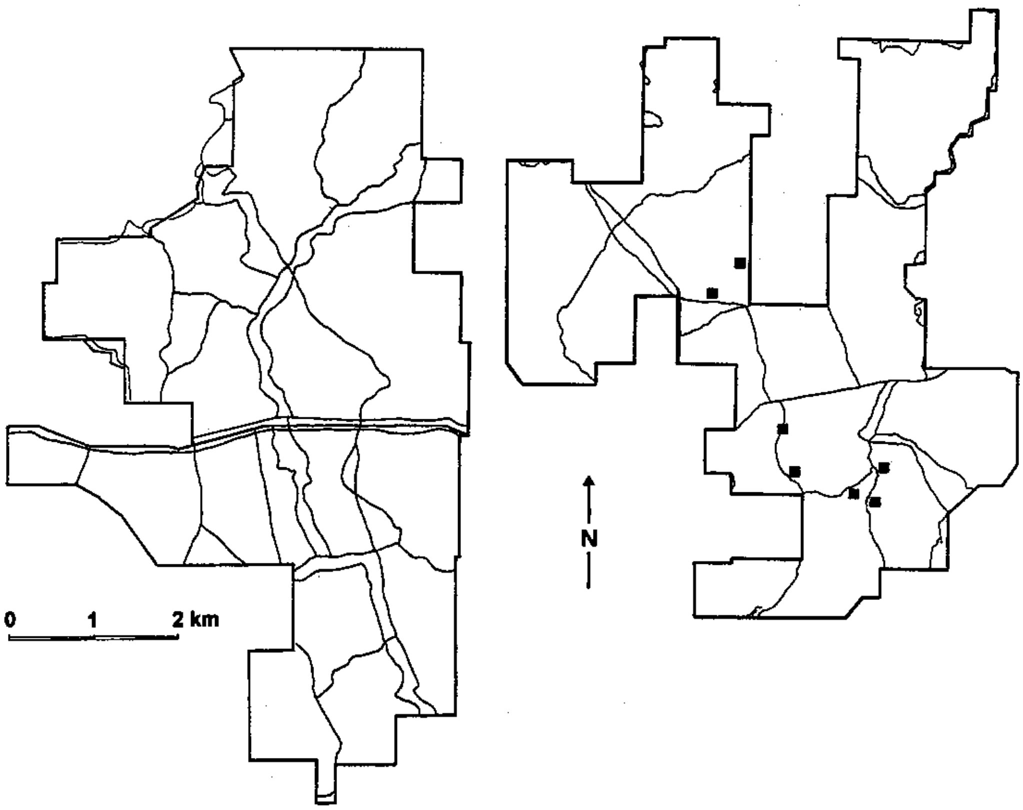


Fig. 6. Eastern and western blocks of Boyagin Nature Reserve, showing perimeter and internal roads. Sites at which numbats were released in 1985–87 are shown as dark squares.

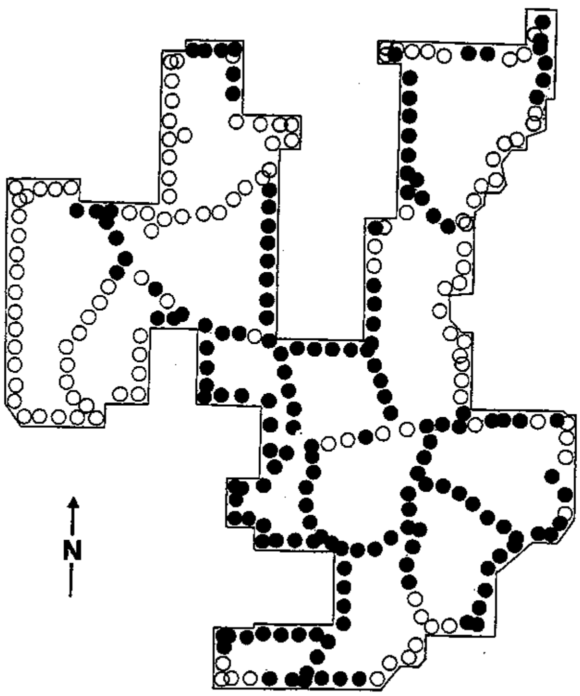


Fig. 7. Results of a survey for numbat diggings and scats in the eastern block of Boyagin Nature Reserve, October/November 1990. Dark circles denote points at which fresh numbat diggings and/or scats were found; open circles denote points at which neither were found.

No numbats were released at Boyagin between March 1988 and December 1992, yet during that time animals moved into all suitable habitat in the eastern block and colonized the western block, albeit at a low level. This indicates that the Boyagin population is now self-sustaining. Two males and a female from Dryandra were released into the western block of Boyagin in February 1993, as part of a programme of exchange of individuals to promote gene flow between isolated populations (Friend 1987).

REINTRODUCTION TO KARROUN HILL NATURE RESERVE

Compared with the Boyagin exercise, the reintroduction at Karroun Hill Nature Reserve has proved much more difficult to monitor. Road access in the reserve is very limited, and the animals are able to disperse over a much larger area. After difficulties experienced in monitoring the first release (1986), the relocation rate for radio-collars was greatly increased by the use of two-stage (AVM Instruments P2-1V) rather than one-stage transmitters, the development of a sensitive antenna system for a light aircraft, and the use in 1987 and subsequent years of a scanner (Telonics TS-1). Searches for diggings have had a very low success rate, however, because the numbats occur at low density and areas are often not reoccupied immediately after the death of a resident animal, if at all.

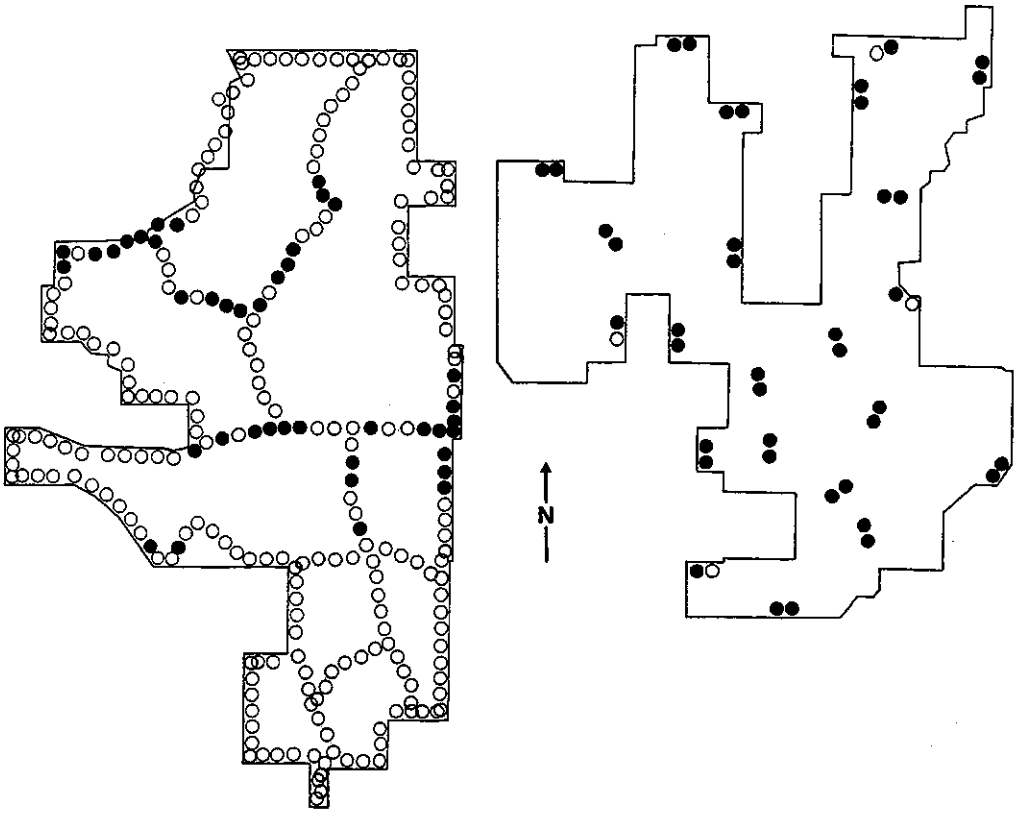


Fig. 8. Results of a survey for numbat diggings and scats in the eastern and western blocks of Boyagin Nature Reserve, October/November 1992. Dark circles denote points at which fresh numbat diggings and/or scats were found; open circles denote survey points at which neither were found. The survey of the eastern block was limited to 22 monitoring sites in suitable habitat.

The low numbat population density and the near absence of roads render sightings surveys from vehicles of little value.

The release sites used in 1987 and subsequent years have been near Karroun Hill itself, a low granite dome in the western half of the reserve. The locations at which numbats were found about one month after release in 1987 and 1988 are shown in Figures 9 and 10, respectively. In 1987, there were no numbats resident in the area at the time of the releases, and only 10 of 15 released animals were found to have stayed within 3 km of the release site. In the following year, when there were already numbats resident in the area, 13 of 14 released animals established home ranges within this area. It seems that the prior presence of numbats in an area increases the probability that newly released animals will settle nearby. Due to the small size of Boyagin Nature Reserve, this tendency had not been detected during the reintroduction there.

A total of 92 animals have been translocated from Dryandra to Karroun Hill in the period 1987–93. Thirty-four young born at Karroun Hill have been captured and fitted with transmitters, usually just before achieving independence. Ten litters are known to have been raised successfully to independence. One female is known to have raised two litters at Karroun Hill and was carrying a third when she was killed, probably by a bird of prey. This female lived for two years and seven months after translocation, achieving the greatest longevity recorded amongst the numbats translocated to this area.

There have been 50 known deaths at Karroun Hill. Forty-four have involved predation, but in only 18 cases could the predator be identified with any certainty. Of these, 10 were due to raptors, four to feral cats *Felis catus*, three to foxes and one to a dingo *Canis familiaris dingo*. None of the deaths appears to have been due to a reptile. Amongst the raptor species present at Karroun Hill, those most likely to take numbats are Brown Goshawks *Accipiter fasciatus*, Little Eagles *Hieraaetus morphnoides* and Wedge-tailed Eagles *Aquila audax*; less likely candidates include Brown Falcons *Falco berigora* and Whistling Kites *Haliastur sphenurus*. The remaining 28 predation records have not been allocated to any predator type, although given that many damaged collars show tooth marks, mammalian predators (fox, cat or dingo) must have accounted for some. Trials are being undertaken in which radio-collars are presented to captive birds of prey, cats, foxes and dingoes in an attempt to record distinctive patterns of damage made by these predators on the plastic-coated brass bands of the collars.

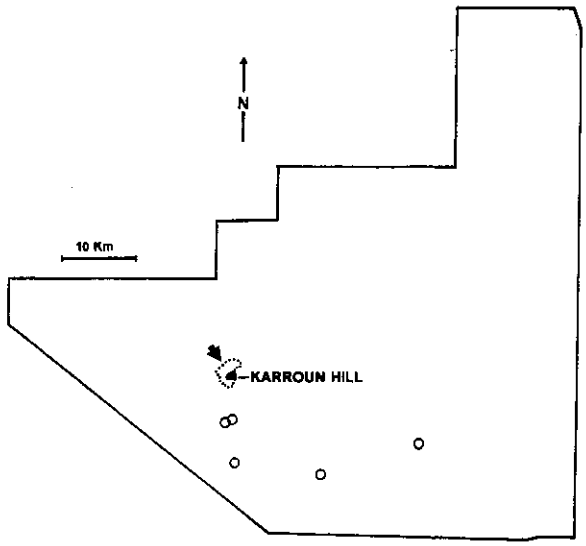


Fig. 9. Locations of 15 numbats, released at Karroun Hill Nature Reserve in November/December 1987, approximately one month after release. The release sites were located within 1 km of Karroun Hill. Ten animals remained within 3 km of their point of release (i.e., within the area marked by the dotted line and arrow). Locations of the five other animals are marked by open circles.

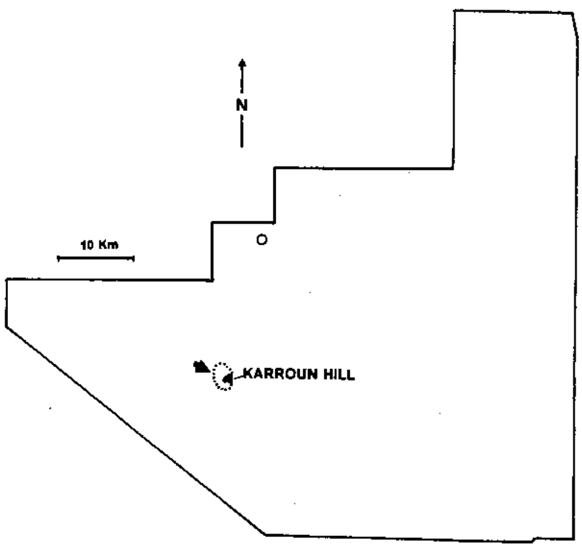


Fig. 10. Locations of 14 numbats, released at Karroun Hill Nature Reserve in November/December 1988, approximately one month after release. The release sites were located within 1 km of Karroun Hill. Thirteen animals remained within 3 km of their point of release (i.e., within the area marked by the dotted line and arrow). The location of the remaining individual is marked by an open circle.

The 44 recorded victims of predation include 28 translocated adults (30% of the animals translocated) and 16 young born at Karroun Hill (47% of the young radio-collared). Rather than reflecting the different origin of the animals, this disparity is more likely to be due to the greater vulnerability of young numbats compared with adults.

In March and September 1990 and 1991, aerial baiting using dried meat baits containing 4.5 mg of 1080 was carried out in an attempt to reduce predation by foxes, at a rate of 7.5 baits per km^2 over an area of 40 000 ha. The first instances of cat predation on numbats at Karroun Hill were recorded during the first year of aerial baiting. Cat numbers have been shown to rise after fox control at other arid and semi-arid sites in Western Australia (Christensen and Burrows 1994; Short *et al.* 1994). Although the cat population at Karroun Hill has not been monitored, it is possible that the removal of foxes and dingoes has also favoured cats in this area. Increases in cat numbers and in the rate of predation by cats following fox control have not been observed, however, in the more mesic westerly areas in Western Australia such as Dryandra, Boyagin and Batalling.

Judging from the lack of readily observed diggings, it is unlikely that a thriving numbat population has become established close to the main release site. In addition to the eight radio-collared animals, however, uncollared animals clearly exist in the reserve: two have been sighted, and a number of radio-collared females remote from all radio-collared males have produced young. The presence of cats is suspected to be hindering the establishment of a population, although raptors are also important predators. While monitoring will continue at Karroun Hill, future work will focus on means of controlling feral cats.

OTHER REINTRODUCTIONS

Three radio-collared female numbats from Dryandra were released at Tutanning Nature Reserve in November 1987 in an effort to determine whether males were still present in the reserve. Two of the females were killed by raptors in the first month, but the third was still alive and wearing a radio-collar in November 1991. She did not produce young during the four intervening breeding seasons, indicating that no male numbats survived in the reserve. More numbats were translocated from Dryandra to Tutanning Nature Reserve in 1991 (14 animals) and 1992 (seven animals), but it is too early to assess the success of this reintroduction. Fifteen numbats, including 10 fitted with radio-collars, were released at Batalling Block in December 1992. An abnormally high rate of loss of signals before the animals were moved from Dryandra indicated a high failure rate amongst the radio-collars, and the loss of our radio-tracking aircraft before the monitoring flight at Batalling meant that we were unable to search efficiently for the signals. These reintroductions will be continued.

DISCUSSION

The establishment and continued growth of the Boyagin population under a regime of fox control indicates that numbat habitat in remnant vegetation in the western part of the Western Australian wheatbelt is still intact. The success of the Karroun Hill animals in producing and raising healthy young suggests that numbat habitat in more easterly regions is also able to provide sufficient food to support populations. The absence of strong evidence that a population has become established at Karroun Hill focuses attention on the threat posed to mammal recovery efforts by the lack of a cost-efficient means of controlling feral cats. Research into methods of control using poisons and into the feasibility of biological control is now under way across Australia (Barrett *et al.*, in press). The interactions between cats, foxes and dingoes are poorly understood, however. It is possible that in some areas dingoes exert control over both foxes and feral cats.

Our experiences at Karroun Hill have also highlighted the need for an objective means of determining the predator responsible for mortality of radio-collared animals. Currently this is done by piecing together the evidence from the mortality site, the condition of any animal remains and the condition of the radio-collar, including an interpretation of the marks left on its plastic coating. Controlled trials in which captive predators are given radio-collars on food items in order to record specific marks are of some value, but some collars are left without distinctive marks in the field.

There is limited potential for other numbat reintroductions in the western wheatbelt of Western Australia, where the likelihood of success appears greatest. One possible site is on the eastern edge of the main forest block, only 6 km west of Boyagin across farmland. The large extent of the jarrah forest and its proximity to population centres and hence to management resources make it an attractive option for reintroduction sites, but the low number of historical records indicates that this environment is probably suboptimum for numbats. The Batalling reintroduction in the eastern jarrah forest will allow this to be assessed. Otherwise, most sufficiently large potential reintroduction sites are in the eastern wheatbelt, or further east in semi-arid and arid regions where feral cats may cause problems.

In addition, it is important that the reintroduction of any species should not be considered in isolation. There is a need to co-ordinate the re-establishment of threatened species so that resources are concentrated at strategic locations, where the previously recorded fauna can be reconstructed (Friend 1991). This process of co-ordination is being carried out in Western Australia through the establishment of recovery teams, and will in part determine the choice of further numbat reintroduction sites.

ACKNOWLEDGEMENTS

We would like to express our thanks to a number of people who have worked with us or assisted us in other ways during the reintroduction projects described here. These include Bruce Turner, Robert Brazell, Pat Doherty, Boyagin neighbours Eric Pech and Graham Watts, Karroun Hill neighbours Brian and Marilyn Kirby, and numerous volunteers. CALM operations staff based at Pingelly have carried out baiting with enthusiasm and regularly informed us of numbat sightings. Numbat sighting rates for 1955 and 1956 shown in Figure 2 are calculated from unpublished data kindly provided by John Calaby. Funds for the initial stages of the reintroductions to Boyagin and Karroun Hill were provided by World Wide Fund for Nature Australia (Projects 94 and 108), through the generosity of an anonymous donor.

REFERENCES

Barrett, J., Carter, D. and Hicks, J., 1994. Control of feral cats in Australia — the Feral Pests Program. *Proc. Assoc. Aust. Vet. Conserv. Biol.*: Canberra (in press).

Calaby, J. H., 1960. Observations on the banded ant-eater *Myrmecobius fasciatus* Waterhouse (Marsupialia), with particular reference to its food habits. *Proc. Zool. Soc. Lond.* **135**: 183–207.

CALM, 1990. A Manual for Fox Control. World Wide Fund for Nature Australia: Sydney.

Christensen, P. and Burrows, N., 1994. Project Desert Dreaming: experimental reintroduction of mammals to the Gibson Desert, Western Australia. Pp. 199–207 *in* Reintroduction Biology of Australian and New Zealand Fauna ed by M. Serena. Surrey Beatty & Sons: Chipping Norton.

Christensen, P., Maisey, K. and Perry, D. H., 1984. Radio-tracking the numbat, *Myrmecobius fasciatus*, in the Perup Forest of Western Australia. *Aust. Wildl. Res.* **11**: 275–88.

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

Friend, J. A., 1987. Local decline, extinction and recovery: relevance to mammal populations in vegetation remnants. Pp. 53–64 *in* Nature Conservation: The Role of Remnants of Native Vegetation ed by D. A. Saunders, G. W. Arnold, A. A. Burbidge and A. J. M. Hopkins. Surrey Beatty & Sons: Chipping Norton.

Friend, J. A., 1989. Myrmecobiidae. Pp. 583–90 *in* Fauna of Australia, vol. 1B. Mammalia ed by D. W. Walton and B. J. Richardson. Australian Government Printing Service: Canberra.

Friend, J. A., 1990a. The numbat *Myrmecobius fasciatus* (Myrmecobiidae): history of decline and potential for recovery. *Proc. Ecol. Soc. Aust.* **16**: 369–77.

Friend, J. A., 1990b. Numbat dawn. *Landscope* **5**(4): 15–19.

Friend, J. A., 1991. Paradise on the edge. *Landscope* **7**(1): 45–48.

Friend, J. A., 1994. Recovery plan for the numbat. Report for the Endangered Species Program, Australian Nature Conservation Agency. WA Department of Conservation and Land Management: Como.

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

King, D. R., Oliver, A. J. and Mead, R. J., 1981. *Bettongia* and fluoroacetate: a role for 1080 in fauna management. *Aust. Wildl. Res.* **8**: 529–36.

Maddock, J., 1987. On the Line: A History of the Shire of Mukinbudin. Shire of Mukinbudin: Mukinbudin.

Maisey, K. and Bradbury, H., 1983. New light on the numbat *Forest Focus* **27**: 14–24.

Serventy, D. L., 1954. The recent increase of the rarer native mammals. V. Dryandra Forestry Station. *West. Aust. Nat.* **4**: 128–29.

Short, J., Turner, B., Parker, S. and Twiss, J., 1994. Reintroduction of endangered mammals to mainland Shark Bay: a progress report. Pp. 183–88 *in* Reintroduction Biology of Australian and New Zealand Fauna ed by M. Serena. Surrey Beatty & Sons: Chipping Norton.

Twigg, L. E. and King, D. R., 1991. The impact of fluoroacetate-bearing vegetation on native Australian fauna: a review. *Oikos* **61**: 412–30.

Youngson, W. K. and McKenzie, N. L., 1977. The wildlife of the proposed Karroun Hill Nature Reserve, Western Australia. Department of Fisheries and Wildlife Report 30. WA Department of Fisheries and Wildlife: Perth.

Mammal Conservation in Western Australia
Re-introduction Case Study

Dasyurus geoffroii - Chuditch

Brent Johnson CALM Woodvale

Since 1992 the Chuditch Recovery Team has authorised three translocations of the carnivorous marsupial *Dasyurus Geoffroii.* These re-introductions have been undertaken by team members assisted by CALM district personnel and volunteers. The chuditch released had been bred at the zoo as part of the recovery plan funded in different stages by CALM, Environment Australia (then ANCA), WWF, Alcoa and the Perth Zoo.

The first of these was undertaken in Julimar Conservation Park (24 000ha) north east of Perth.and at that time thought to be to the outside of Chuditch distribution. Julimar is primarily a mixed forest of jarrah/marri/wandoo and was thought suitable for this species. This work has also received financial and logistical support from the Department of Defence due to the proximity of their Bindoon training facility.

Some 52 Chuditch were released in the period September 1992 to March 1993. Following some years of close monitoring by CALM Science personnel this population was found to be well established. During the most recent visit in July 1998 mean daily capture rates had risen to >9%.(78 captures of 34 individuals). It is now common for most captured females to be found with pouches full of the maximum (6) young during the annual visit. Sightings by nearby landholders and unfortunately an increase in roadkills have also been recorded. Responsibility has now been handed over to CALM Mundaring for continued monitoring as part of their commitment to CALM's Western Shield program.

Following on from this success the Recovery Team decided to attempt to re-introduce chuditch back to areas well outside of their current distribution.The first such translocation took place in October 1996 when 40 captive bred chuditch were released into Lake Magenta Nature Reserve (108 000ha) some 400 km South East of Perth. This reserve contains large areas of eucalypt mallees and woodlands with surrounding heath and scrublands. It is considered to be semi-arid and historically would have been capable of supporting a diverse range of fauna. As per Julimar these animals were closely monitored, this time by staff from CALM Science and CALM Katanning. A combination of radio-tracking and trapping has been undertaken since then and a further 41 chuditch have been added to the original batch.

From the information gathered we could see that the released chuditch responded to their new found freedom in various ways. Some moved over considerable distance

(20km) in the space of a few days whilst others quickly established territories close to the release point.

This population appears stable although the threat from foxes and cats, which are regularly sighted around the reserve boundary, is ever present and some predation has occurred. Breeding occurred in the first year of release with several captures of offspring being recorded in 1997. Further monitoring will be conducted over the next few years and possibly some further research into the dietary and habitat requirements of chuditch in semi-arid areas such as Lake Magenta. This is importan because all biological data known about the chuditch comes from forest areas where dietary and home range requirements may be quite different.

The ability of the Perth Zoo to successfully produce chuditch for this program has allowed additional translocations to be scheduled and in March 1998 a further 2(chuditch were released into Cape Arid National Park 150km beyond Esperance.. This translocation was designed to expand our knowledge of how chuditch would adapt to different habitats as the park is considerably to the east of Lake Magenta an(contained a mix of coastal and semi-arid vegetation associations.

With the assistance of the resident CALM Ranger, these individuals were again closely monitored. This work produced some interesting information. Firstly, after a period of weight loss the chuditch returned to release weight within 4-6 weeks; For refuge they were found to prefer rabbit burrows both disused and those currently occupied; they did not mind tackling large prey as we observed the demise of rabbits, a young Goshawk and we found a feral cat claw in one chuditch scat.

A further 20 were released in late April and we have already observed the birth of the first generation of Cape Arid chuditch. The site will be closely monitored as feral cats have been sighted and trapped during this re-introduction phase and may pose a threat, particularly to the young animals born at the park. This cat presence i not surprising when you read passages from the old Israelite Bay jetty logbook that state; "arrived today: 100 cats - to keep the rabbits down".

We were also pleased that most stayed close to their point of release perhaps indicating that adequate food and shelter were available in that area. One exception was a male from the second batch who was captured by local CALM Wildlife Officers in a chook pen North west of Salmon Gums some 10 weeks after release. This adventurous individual had travelled over 180km "as the crow flies" and was found to be in excellent condition.

These translocations appear successful or likely to be so. Additional areas for future releases are currently being assessed, however all sites are still dependent on continued fox baiting, regular monitoring by CALM staff and careful management of the area to assist in the creation of vibrant and strong populations. It is envisaged that captive breeding will continue to be the primary source of Chuditch for this work in the foreseeable future

The Dibbler

By A.N. Start

1. What is a dibbler?

The dibbler, *Parantechinus apicalis,* belongs to the family of carnivorous marsupials known as the Dasyuridae. Most dasyurids weigh less than 100 grams. In Western Australia the Pilbara Ningaui, *Ningaui timealeyi,* may weigh as little as 2 grams but a large male Chuditch, *Dasyurus geoffroyi,* can weigh over 2 kilograms. Tasmanian Devils are the modern giants of the family.

Male dibblers weigh up to 100 grams and sometimes a little more but females are smaller, sometimes less than 40 grams. Their appearance is superficially rodent-like but they have more pointed noses. Of course, their anatomy is typical of small marsupials and their dentition is adapted to an invertebrate diet. Dibblers can be distinguished from other similar dasyurids and, in southwest Western Australia, from all other small mammals, by a distinct, pale eye-ring. Each hair has a dark band and pale tip that gives the animals a speckled appearance (they have been called Freckled Antechinus). Their lightly furred tails taper to a point.

Dibblers are not strictly nocturnal. Although they are seldom seen, they are sometimes trapped during the day and the captive dibblers in Perth Zoo often move about in the daytime. They seem to spend a lot of time on the ground where they "swim" through deep leaf litter when it is available but they also climb small trees and visit *Banksia* blooms. They are said to hold their tails in a characteristically upright position when running across open spaces. Most of their food items are insects and other invertebrates but (at least on Boullanger Island) they will occasionally eat mice, birds and lizards. Evidently they like Banksia nectar and, on Boullanger Island they relish ruby saltbush berries in summer.

Dibblers breed seasonally, commencing in their first year. Mating occurs in March or April; gestation is about 45 to 50 days and up to eight young are born about June. At first they remain attached to their mother's nipples but later they are left in a nest until they become independent at about four months old, in spring. Males of many smaller dasyurid species die after mating, leaving a population of adult females and juvenile animals. Chris Dickman recorded a male die-off after the breeding season on the Jurien Islands but observations on the same islands and in Fitzgerald River National Park during in the last three years have shown that many males survive and breed in subsequent years.

No modern biologists have seen wild nests. In the 1840s John Gilbert was told by Aboriginal People living near Moore River that they nest *"in a slight depression of the ground beneath the overhanging leaves of the Xanthorrhoea"* but near Perth, Aboriginals caught them *"in dead stumps or amongst the grasses of Xanthorrhoea"*. At King George's Sound they were said to nest in a raised structure of finer twigs and coarse grass. On the Jurien Islands they often enter shearwater or storm petrel burrows and probably nest in them. On the mainland they may use burrows, but collared animals that have been in one place for sometime during the day, move off when approached. This suggests they may also sleep above ground, corroborating the information given to Gilbert.

2. Discovering Dibbers.

Gray described the species in 1842 using a specimen he obtained from "*Mr. Brandt of Hambourgh, who purchased it during his late visit to London. Its precise habitat is not known, but it is doubtless from Australasia.*" Up to 1884, various people collected several more. Fortunately, John Gilbert (who was employed by the artist, John Gould, to collect wildlife in Western Australia) obtained several specimens for he was the only nineteenth century naturalist to kept precise locality data or write notes on its natural history. His hand-written notes to Gould (which still exist) provided most of the text accompanying the dibbler plate in Gould's *The Mammals of Australia*. The last of the early collectors to take a dibbler was Tunney. In 1904, he caught one in a hollow log at Gracefield near Kojonup. It is in the Dublin Museum.

3. Rediscovering Dibblers.

The dibbler was not recorded again for 63 years by which time it was assumed to be extinct. But, in 1967, Perth wildlife photographer, Michael Morcombe, set cunningly-designed traps around *Banksia* flowerheads at Cheyne Beach, east of Albany. He hoped to catch and photograph honey possums. Instead, he caught a dibbler. The story (see Further Reading, below) is well worth reading.

More dibblers were caught near Cheyne's Beach in the succeeding months but none have been taken there recently. However, since then dibblers have been found at several locations on the south coast. Dr Vic Smith trapped the western-most dibblers in Torndirrup National Park. A farm cat caught the eastern-most animal near Jerdacuttup, south of Ravensthorpe. Since then dibblers have been caught alive at several sites in the heaths of Fitzgerald River National Park. The first one was found dead on a track; it was probably a cat victim too.

One of the most significant, recent discoveries was dibbler populations on Boullanger and Whitlock Islands, two small islands near Jurien, about 200 km north of Perth. CALM Technical Officer, Phil Fuller found them there in 1985.

4. Dibbler distribution

Since European settlement live dibblers have been collected north of Perth from Wanneroo, two islands near Jurien, sand plains near the Moore River (close to modern day New Norcia). Along the south coast they have been caught between King George's Sound and Torndirrup National Park east to Jerdacuttup and inland to Kojonup. However they are known from sub-fossil remains as far north as Shark Bay and as far east as Israelite Bay in WA as well as the Eyre Peninsula in South Australia. The species may have contracted from the extremities of this range before Europeans arrived. Gould received a specimen said to have come from South Australia but it seems to be lost and the record is doubtful.

It is significant that there are no recent sub-fossil records in the high-rainfall, mostly forested, southwest between Perth and King George's Sound. There are also no records from the more arid country inland of the wheatbelt other than the Shark Bay specimens and a sub-fossil specimen from Peak Charles (between Esperance and Norseman).

5. The formal conservation status of Dibblers.

The dibbler is classified **'Endangered'** by ANZECC (1991), the Commonwealth *Endangered Species Protection Act*, and the Action Plan for Australasian Marsupials and Monotremes (Maxwell *et al.* 1996). In Western Australia it is declared by the Minister to be **"Fauna that is likely to become extinct or is rare"** under the *Western Australian Wildlife Conservation Act 1950.*

6. Early research.

The collectors of the last century did little more than record (often very imprecisely) the locations from which they obtained specimens although Gilbert was meticulous and recorded information on natural history of all the species he encountered. His manuscript notes to John Gould, his employer, have survived and Gould did little more than edit them for the text of his classic folios on Australian mammals.

7. Recent Research.

In January 1995 CALM began a three year research program that was funded by the (then) Endangered Species Unit of the Australian Nature Conservation Agency (now Environment Australia). The objective was to learn enough about dibblers to write an Interim Recovery Plan and implement it from 1998 onwards. This has been the focus of dibbler work over the past three years. In 1996, a Recovery Team was established to guide the program's priorities and tap the expertise that various people had to offer.

8. Work on south coast

Much of the work in the first year sought to re-survey sites where dibblers had been located since their 1967 re-discovery and to locate new populations. They were found only in the Fitzgerald River National Park (FRNP) although looking for dibblers is like the proverbial needle in the haystack and much of the haystack is still untouched. Nevertheless the second year focused on learning as much as possible about one easily accessible population in the FRNP.

There were many problems, not the least being their mobility (they regularly moved out of range of radio transmitters fitted to collars) and their tendency to abandon sites. At the end of the day, we did not have the ability to closely follow individuals or populations through time and space. Nevertheless we learned a lot about their conservation needs in the FRNP.

9. Management issues on the mainland.

FRNP is clearly a strong hold for dibblers on the south coast. This is a large Biosphere Reserve that contains several other threatened animals as well as one of the world's most diverse floras. Management of the FRNP is in accordance with a Management Plan that recognises the presence of rare species including dibblers. The principal issues are:

- **Fire.** All modern dibbler records are from long un-burnt vegetation (or very close by). The Management Plan recognises this requirement (which is shared by some other threatened species) and prescribes strategies to minimise the chances of wildfire destroying all suitable habitat.

- **Dieback disease.** Pathogenic *Phytophthora* species are already present, but localised, in FRNP. Much of the FRNP's diverse flora is susceptible to *Phytophthora*-caused dieback diseases that can drastically alter its diversity, composition and structure. Although such changes are likely to be detrimental to dibblers, they would be devastating to other conservation values. For this reason there are very strict quarantine rules governing access to and movement in the Park (even dibbler research stops when the soil is wet). While these measures will prevent human spread of the pathogens, natural spread will continue. However CALM is researching the aerial application of phosphonate to contain the disease and FRNP is one of the areas where these experiments are being conducted.
- **Feral predators.** Foxes and cats are present in FRNP. It is highly likely that foxes kill dibblers and cats are known to do so. The Park is aerially baited for foxes under CALM's Western Shield program and CALM has stepped up research into methods for cat control over large areas.
- **Translocation.** Although the establishment of new populations in safe areas has been a useful tool in the recovery of several threatened species, one has to be able to follow the fate of the founder animals to determine the success and, more importantly, to identify and minimise any problems that they encounter. Radio tracking is the best method for cryptic animals like dibblers. However, as mentioned before, we have difficulty maintaining contact with radio-collared dibblers.

In summary dibblers seem to be widespread, if patchy, in FRNP where all that can be done is being done to maintain their habitat and minimise threats. CALM will continue to monitor dibblers in FRNP and will be trapping in other areas of the south coast where dibblers may persist as part of Western Shield. As developing technology improves our ability to manage dibblers, it will be applied.

10. Management issues on the Jurien islands.

The two populations on small islands off Jurien are adapted to a very different climate and habitat to those on the south coast. It is thus important that their genetic strain is maintained for the future recovery of dibblers and to improve their capacity to deal with climate change. There are several factors that need attention by managers. These are:

- The populations, being restricted to two small islands, are small (perhaps a hundred animals on each island) and very vulnerable to disasters.
- The dibblers use seabird burrows for foraging, shelter and perhaps for nest sites. Reduction in the number of seabirds breeding on the islands might affect dibblers.
- House mice have been introduced to both islands. Dibblers will sometimes feed on the mice but we do not yet know whether mice are competing for resources that dibblers require. If the latter is the case, the "crunch" might come in a particularly hard year (eg. in times of drought or after a fire).
- There are not yet any feral predators on the islands, but they are popular places close to a holiday town so there is a risk of cats, in particular, getting there.
- Fortunately there are few aggressively invasive weeds on the islands, the alkaline soils are not conducive to *Phytophthora* and the salty, coastal vegetation is less fire-prone than many. Nevertheless these are potential threats that need careful assessment and contingency plans.

11. Captive Breeding and Translocation. A captive colony offers several benefits including:

- Development of husbandry techniques for dibblers in case we have to resort to captive breeding of mainland populations or rescue animals from the islands following a disaster (eg. fire)
- Insurance against disasters wiping out the wild populations before dibblers can be salvaged
- Stock for introduction to new sites (eg a mouse-free island)
- Opportunity to study the reproductive biology of dibblers.

Four pairs, two from each island, were brought to Perth Zoo in 1997. Three females gave birth to twenty one young, of which nineteen were raised. One female died. The 1998 the breeding program was also successful and in October this year twenty eight dibblers were released onto Escape Island.

Their new home is also near Jurien. The habitat is very like that on Whitlock Island but Escape Island has twice the area of Whitlock. Rocky shorelines and shallow water make it much more difficult to land on and, anyway there are no nice beaches like those on Boullanger Island, so it is less prone to visitors (and their abandoned cats, dogs or fires). It has lots of shearwater burrows but no house mice on it.

12. Recovery Team Commitment

The success of this project has been due to the involvement of many people. Representation on the Recovery Team is indicative of the diversity of skills that people and organisations have been willing to contribute. It involves:

- CALM Scientists and managers,
- Community members from Jurien and the south coast
- Perth Zoo (and the Marsupial CRC) scientists and keepers
- University of WA post graduate students and their supervisor
- Corresponding members who have researched dibblers in the past at La Trobe University and University of Sydney
- Consultant zoologists
- Environment Australia

The Recovery Team has written an Interim Recovery Plan that is now the basis for the projects next three years. One of the Objectives in the IRP is preparation of a full Recovery Plan to take its place thereafter.

13. Further reading.[1]

Chapman, A. and Newby, K.R., 1995. A biological Survey of the Fitzgerald area, Western Australia. *CALMScience* **Supplement 3:** 1-258.

Dickman, C.R. and Braithwaite, R.W. 1992. Postmating mortality of males in the dasyurid marsupials, *Dasyurus* and *Parantechinus*. Journal of Mammalogy **73 (1):** 143-147.

[1] The bibliographies in these references will lead interested students to further publications. Tony Start or Tony Friend, both at CALM's Wildlife Research Centre, Woodvale, will help any student who can not access any of these documents.

Fuller, P.J. and Burbidge, A.A. 1987. Discovery of the dibbler, *Parantechinus apicalis*, on islands at Jurien Bay. *The Western Australian Naturalist* **16:** 177-181.

Gould, J. 1863. *The Mammals of Australia.* Taylor and Frances. London.

McCulloch, C. 1998. *The demography and habitat use of the dibbler* (Parantechinus apicalis) *on two islands in Jurien Bay, Western Australia.* Thesis for Graduate Diploma of Natural Resource Management, Faculty of Agriculture, University of Western Australia. 1-60.

Moore, S., Cavana, M., Gillen, K., Hart, C., Hopper, S., Orr, K. and Schmidt, W. 1991.
Fitzgerald River National Park Management Plan; 1991 - 2001. Department of Conservation and Land Management. Perth.

Morcombe, M.K. 1967. The rediscovery after 83 years of the dibbler *Antechinus apicalis* (Marsupialia, Dasyuridae). *The Western Australian Naturalist.* **10(5):** 103-111.

Ride, W.D.L. 1970. *A guide to the native mammals of Australia.* Oxford University Press. Melbourne.

Start, A. N., 1998. Dibbler, *Parantechinus apicalis,* interim recovery plan. 1998-2000. Department of Conservation and Land Management. Perth

Valente, A. and Woolley, P.A. 1982. The Dibbler, *Parantechinus apicalis* (Marsupialia: Dasyuridae): Failure to locate populations in four regions in the south of Western Australia. *Australian Mammalogy* **5(3&4):** 241-245.

Woolley, P.A. 1977. In search of the Dibbler, *Antechinus apicalis* (Marsupialia: Dasyuridae). *Journal of the Royal Society of Western Australia.* **59 (4):** 111-117.

Woolley, P.A. 1980. Further searches for the Dibbler, *Antechinus apicalis* (Marsupialia: Dasyuridae). *Journal of the Royal Society of Western Australia.* **63 (2):** 47-52.

Health Monitoring in the Field

Dr Sherri Huntress

DISEASE IN MARSUPIALS

D.W. Cooper
School of Biological Sciences, Macquarie University, NSW 2109
CRC for Conservation and Management of Marsupials
Macquarie University NSW 2109

Like all living things, marsupials are subject to disease. And like most organisms, we know very little about the ones to which they are subject. In this talk, I will discuss two conditions to which they are subject and which are of contemporary interest. The first is bovine tuberculosis in the Australian brush-tailed possum in New Zealand. This is now of considerable economic importance because the possums are acting as the principal reservoir of the disease for cattle. The general biology, epidemiology and possible control measures will be discussed.

The second disease is toxoplasmosis, a protozoan pathogen whose definitive host is the domestic cat. Since cats have only recently arrived in Australia, marsupials have no history of evolutionary resistance to toxoplasmosis. It is speculated that this disease could have had an undetected impact on marsupial species in the immediate past. The data which do exist on its presence in marsupials will be discussed.

Both diseases raise the general question of the importance of introduced pathogens in mammalian conservation biology. The need for an ongoing national body to address this question will also be briefly referred to.

BILATERAL CATARACTS IN CAPTIVE GREATER STICK-NEST RATS (*Leporillus conditor*)

Des Cooper[1], Sue Conaghty[2], Suzy Barlow[3], Peter Copley[4]

[1]School of Biological Sciences, Macquarie University,
CRC for Conservation and Management of Marsupials
[2]Veterinarian, Royal Zoological Society of South Australia
[3]Captive Program Coordinator, Adelaide Zoo
[4]Recovery Program Coordinator, Department of Environment Heritage and Aboriginal Affairs, South Australia

The Greater Stick Nest-Rat (also known as the Wopilkara) became extinct on the Australian mainland in the 1930s. It still exists on the Franklin Islands of Nuyts Archipelago in the South Australian end of the Great Australian Bight. In 1985 the South Australian Department of Environment, Heritage and Aboriginal Affairs (DEHAA) established a breeding colony at the Monarto Faunal Complex. The purpose of this colony is to provide animals for re-introductions. Other captive colonies have been set up at the University of Adelaide, Alice Springs Desert Park, and Adelaide, Taronga and Perth Zoos. Wild colonies have been established on Salutation Island in Western Australia and Reevesby and St Peters Island in South Australia.

In 1997/98 a 24% incidence of bilateral cataracts was found to exist in the captive colony at the Monarto Faunal Complex. The Perth figure is 29% and at Taronga 100%. On Franklin and Reevesby Islands the incidences are 7% and 1%.

There are four possible categories of disease to which these cataracts could belong: metabolic: systemic infection: exposure i.e. environmental: genetic. A considerable body of family data has been collected, principally in Adelaide. A SPARKS database allows easy access to this. The aim of this presentation will be to advance the hypothesis that the condition is genetic in origin. How such a high incidence has arisen will be the subject of speculation. The scientific and conservation importance of the issues will be examined.

Habitat Restoration Ecology

Grant Wells - King's Park / UWA

Rehabilitation of land degraded by human activity has been undertaken for centuries, as far back as the seventeenth century. This presentation seeks to explain the objectives of modern restoration, the protocols designed to attain these objectives and how measures are derived and implemented to evaluate the success of the restoration protocol.
A modern definition for restoration is:

> "The revegetation of an area to a condition perceived to provide the most social benefits and which replicates a former vegetation cover of the site in terms of floristics, physiognomy, productivity and biomass such that natural processes occur ensuring self sustenance."

There are seven characters of an ecosystems commonly targeted for restoration;

- *Composition*: species richness and density.
- *Structure*: vertical arrangement of vegetation and soil components.
- *Pattern*: horizontal arrangement of vegetation and soil components.
- *Heterogeneity*: a variable comprising the above three characters.
- *Function*: Occurrence of ecological processes, eg. nutrient transfers.
- *Dynamics/resilience*: occurrence of successional processes and ability to recover from disturbance.
- *Genetics:* return of the local provenance

Processes considered essential to restoration include:

- Amelioration and removal of causes of decline.
- Definition of realistic goals for restoring species and functional ecosystems with consideration to ecological, socio-economic and cultural impediments.
- Development of procedures to attain restoration objectives.
- Development of criteria for evaluating success of restoration.
- Continuous monitoring and evaluation of success aimed at identifying procedural adjustments which result in continuous improvement.

Propagule Sources for Restoration of Native Vegetation

There are five sources of propagules which may be exploited for the restoration of disturbed areas to a state resembling native vegetation:

- *topsoil*
- *mulch*
- *voluntary colonisation*
- *broadcast seed*
- *greenstock*

Protocol for Plant Propagation

A propagation protocol similar to that used by Alcoa:

- monitoring rehabilitated areas to determine whether the species returns via respread topsoil; mulch or voluntarily colonisation.
- evaluation of seed germinability involving presowing treatments to stimulate germination.
- assessment of seed viability if inviable determine whether:
  - harvest time incorrect
  - plant does not produce viable seed
- vegetative propagation
  - cuttings and direct transplants
  - micropropagation

Evaluation of Revegetation Success

Completion criteria are established by chronosequential observation of natural populations. Growth and survival; reproductive effort and establishment of resilient regeneration propagules e.g. soil seed bank., canopy seed, and resprouting capacity of plants in natural populations are undertaken to compare with the same measures conducted for plants in rehabilitated areas.

ABSTRACT FOR: MAMMAL CONSERVATION IN WESTERN AUSTRALIA

Alcoa Case Study

John Gardner
Environmental Manager, Mining
Alcoa of Australia, Limited

Alcoa of Australia Limited mines bauxite in the jarrah forest of south-western Australia. Approximately 550 ha. are mined each year. At the completion of mining, all areas are rehabilitated. Conservation of the forest's flora and fauna is an important aim of the company's environmental management program. As the surrounding forest provides the source of recruitment for fauna following mining, a significant component of fauna management takes place in unmined forest. For mammals this includes habitat management (eg. minimising impacts on surrounding forest), pre-mining surveys, long term monitoring and research, supporting relevant studies on particular rare species such as the Quokka, and contributing to the conservation of key species through participation in the Chuditch Recovery Team and sponsoring Operation Foxglove.

The overall objective of the post-mining rehabilitation program is to 'restore a self-sustaining jarrah forest ecosystem, planned to enhance or maintain water, timber, recreation and conservation values.' The specific conservation goal is to 'encourage the development of floral, faunal and soil characteristics similar to those of the indigenous jarrah forest ecosystem'. Rehabilitation operations, supported by ongoing research programs are undertaken to help achieve this goal. Operational techniques important for promoting mammal return include the re-establishment of a diverse forest ecosystem, installation of log piles for shelter, and the use of nest boxes to detect the presence of species which are difficult to trap, such as the Brush-tailed Phascogale. Long term fauna monitoring programs are conducted to assess patterns of mammal recolonisation as well as trends in unmined forest. All upland mammal species have been recorded in rehabilitated mines. Recent monitoring has shown marked increases in the numbers of Chuditch, Southern Brown Bandicoots and Common Brushtail Possums in both rehabilitation and unmined forest. The decline in Foxes due to Operation Foxglove is thought to be responsible for this.

Research is now investigating links between fauna recolonisation and the use of fire in rehabilitation.

THE WESTERN PEBBLE MOUND MOUSE TRANSLOCATION PROGRAM:

The Role of Mining Companies in Mammal Conservation

S.D. Anstee
Environmental Affairs. Hamersley Iron Pty. Limited.
G.P.O. Box A42, Perth WA, 6837

ABSTRACT

The Western Pebble Mound Mouse (Pseudomys chapmani) is found throughout the Pilbara region of Western Australia. When first described in 1980, very little was known of the biology of this species. This situation, together with an apparent contraction of its range, prompted its declaration on Schedule 1 of the Wildlife Conservation Act (1950) as a species that is rare and endangered and likely to become extinct. The frequent presence of P. chapmani on iron ore deposits represented a major conservation issue for mining companies. Early attempts to develop management plans for this species were hampered by a lack of basic biological and life history data. On this basis Hamersley Iron Pty Ltd. and other Pilbara iron ore producers undertook research program to help better understand the biology of P. chapmani. Research on P. chapmani was broken into 3 separate components. The first involved a long term regional survey of the Pilbara to fully document the distribution of P. chapmani mounds. The second program documented the social structure and patterns of movement of P. chapmani. The final program developed and undertook the translocation of P. chapmani away from high disturbance mining areas to areas that will not be disturbed. Data from industry based studies were extensively used in a recent review of the conservation status of P. chapmani. This review concluded that P. chapmani populations in the Pilbara are far more stable than originally thought. The review recommended that P. chapmani should be deleted from Schedule 1 and allocated to the IUCN (1994) Red List category of "Least Concern".

INTRODUCTION

Over the past 20 years there has been a growing awareness within Australia of the importance of biodiversity conservation with particular importance being placed on native mammal conservation. In 1993 Australia became a signatory to the 1992 Convention on Biological Diversity. As a part of this ratification the Australian government has agreed to a number of initiatives including a National Strategy for the Conservation of Australia's Biological Diversity.

The Strategy recognises a number of important facts, including;

- that there are many endangered species and ecosystems that are not protected in the reserve system.
- current land tenure arrangements in Australia preclude widespread expansion of the reserve system as a means of improving biodiversity conservation

These factors significantly raise the importance of off reserve initiatives and cooperative agreements as a means of promoting biodiversity conservation.

The Federal Government has stated that the contribution of the Private sector as critical to the successful development and implementation of the National Strategy for the Conservation of Australia's Biodiversity (Environment Australia, 1998). Within the private sector, the mining industry is recognised as becoming a key contributor to conservation within Australia. To this end the mining industry is already making important contributions through numerous areas:

- Baseline research as part of project approvals constitutes a significant portion of the biological survey work being conducted in Australia.
- Species protection programs that manage and ameliorate the impacts of mining on native plant and animal species.
- Mine site rehabilitation programs that promote the regeneration of native ecosystems.

This paper details the level and importance of mining company involvement in endangered species management programs.

THE WESTERN PEBBLE MOUND MOUSE

The Western Pebble-mound Mouse, *Pseudomys chapmani*, is a small native rodent endemic to the Pilbara region of Western Australia (Kitchener, 1980). *P. chapmani* is significant in that it is one of only three species of Australian rodent which builds a permanent above ground structure of pebbles over a subterranean burrow system (Start, 1996). In the Pilbara *P. chapmani* generally inhabit rocky slopes with little or no soil in which to burrow, but with a plentiful supply of pebbles (Dunlop & Pound, 1981). The purpose of the mound of pebbles above the burrow system remains a mystery.

After its initial description very little research was carried out on the biology of *P. chapmani.* This lack in our understanding of the biology of *P. chapmani,* together with an apparent contraction of its range, from a Pilbara Gascoyne distribution, to what were thought to be remanent populations in the central Pilbara, prompted its declaration on Schedule 1 of the Western Australian Wildlife Conservation Act (1950) as a species that is rare and endangered and likely to become extinct.

Throughout much of its range *P. chapmani* comes into conflict with iron-ore mine developments, with both the mice and the mining industry having a liking for the same types of topography and geology.

CONSERVATION ISSUES

Since the beginning of this decade, Hamersley has proposed and successfully developed several major iron ore projects in the Pilbara. During the environmental assessment of the Marandoo Project in 1992, the community indicated a strong interest and concern in the conservation status of *P. chapmani.* Of the 600 public responses to the ERMP 133 raised concerns about the effect of the project on the conservation status of *P. chapmani* in the Pilbara.

In response to these concerns, Hamersley embarked on a research program to provide details of *P. chapmani* biology so that effective management programs could be developed. Specifically the research program involved:

- Long term regional survey of the Pilbara to document the actual distribution of *P. chapmani* in the Pilbara.
- Development of a fast reliable system of determining if mounds are actually being occupied by *P. chapmani.*
- An examination of the social structure and patterns of movement of *P. chapmani.*

This work culminated in the development and implementation of a translocation study for the removal of *P. chapmani* away from areas of mine site disturbance. The study was implemented as part of the broader Yandi environmental management program.

RANGE AND DISTRIBUTION SURVEYS

Range and distribution surveys were commenced in 1991 (Fig. 1) with a number of consultant based surveys being conducted in and around Hamersley's Marandoo project area (Ninox, 1991). Early work focused on areas within the Marandoo project area and adjacent Karijini National Park. Broader regional surveys were commenced in August 1992 with a linear survey that extended from Karratha in the north through to the Collier range in the south (Piggott, 1992). In October 1992, the Gregory Range and Rudall River National Park in the eastern Pilbara were surveyed for the presence of *P. chapmani* mounds (Piggott, 1992b). A third survey targeting the western Pilbara and northern Gascoyne was conducted in May 1994 (Piggott, 1994). These surveys provided the first sets of data that indicated that the perceived range of *P. chapmani* was much greater than originally thought. The August 1992 survey recorded a total of 76 mounds from 5 locations, while the October survey recorded 136 mounds from 2 locations. A breakdown of the number of mounds recorded and mice captured during surveys in 1992 is given in Table 1.

Table 1. Number and location of mounds recorded during *Pseudomys chapmani* range surveys.

Location	Date	No. Active Mounds	No. Inactive Mounds	No. Mice Trapped
Chichester Range N.P.	Aug 92	30	21	1
Mt. Bilroth	Aug 92	5	0	0
Karijini N.P.	Aug 92	5	5	0
Pamelia Hill	Aug 92	7	4	0
Collier Range N.P.	Aug 92	1	3	0
Gregory Range	Oct 92	89	-	5
Rudall River N.P.	Oct 92	24	23	2

It should be noted that while these surveys played an important role in redefining the range of *P. chapmani* in the Pilbara, they were very focused in their aerial extent (Fig. 1) and thus were not able to provide much information on the distribution of *P. chapmani* within its range. One of the major constraints to conducting intensive range and distribution surveys in a region as large as the Pilbara is the high cost of surveying large tracts of land.

As part of their normal duties, Hamersley exploration personnel walk, drive and fly over vast areas of the Pilbara. By way of an example, in 1995 exploration personnel walked over 700 line kilometres. With this in mind Hamersley's Environmental Affairs department embarked on a program to involve the company's exploration personnel in the *P. chapmani* research program. The use of incidental sightings from exploration personnel resulted in the generation of records of *P. chapmani* distribution on both a regional and local basis. To facilitate the collection of this data, exploration personnel were issued mound identification sheets which provided step by step instructions on how to score the level of activity of a mound.

Prior to 1991 the extent of occurrence of *P. chapmani* could be calculated from WA Museum specimens as approximately 44 000 km^2. By the completion of the regional surveys, the extent of occurrence (based on the presence of active mounds) had been increased to 114 900 km^2(Piggott, 1994). A recent review of the conservation status of *P. chapmani* calculated the area of current extent of occurrence as 220 400 km^2 (Start, 1996).

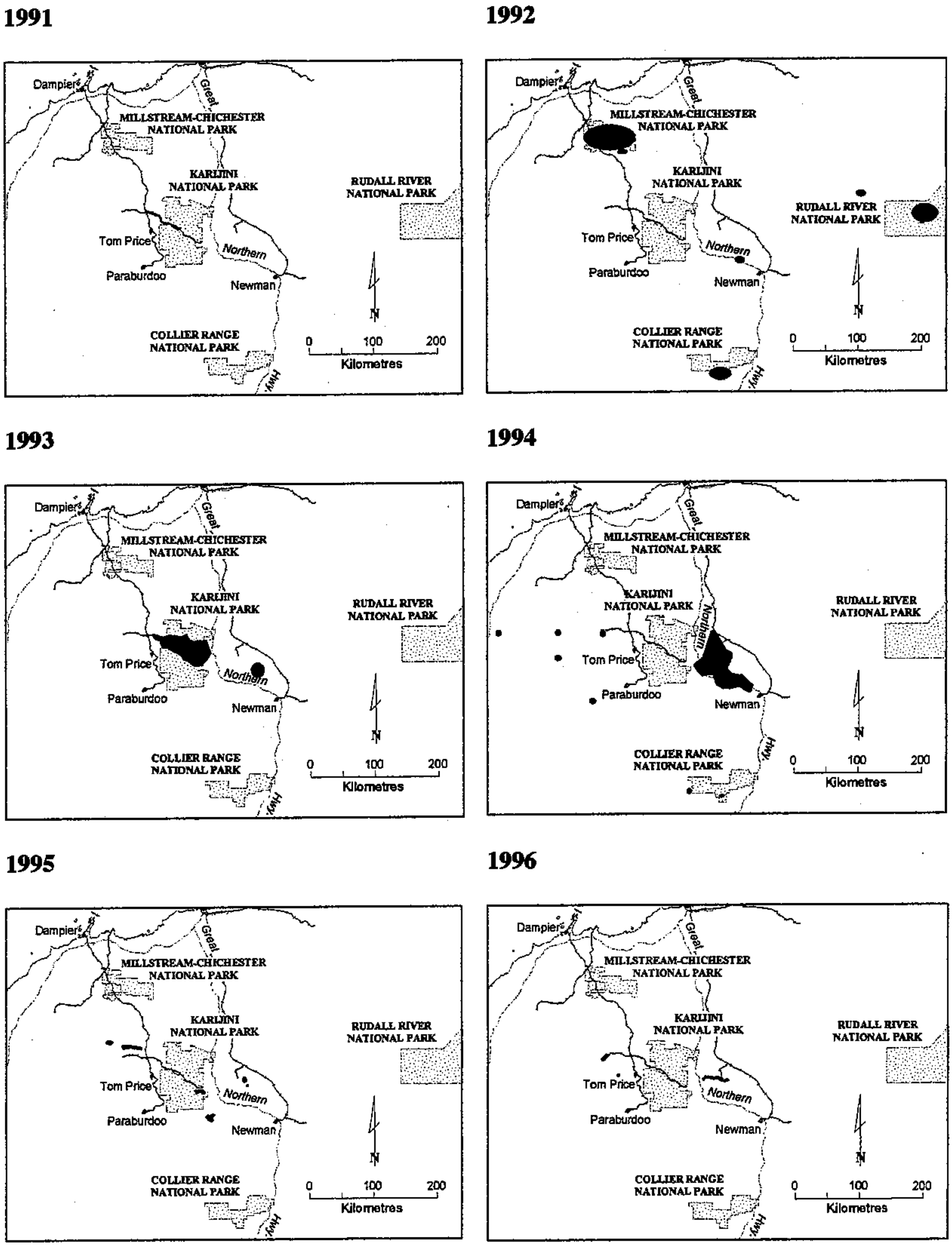


Fig. 1 Geographic survey coverage of *Pseudomys chapmani* in the central Pilbara from 1991 to 1996. Black areas indicate survey areas.

SPECIFIC BIOLOGICAL RESEARCH

While the range and distribution work was important in documenting the extent of occurrence of *P. chapmani* mounds, it was not able to provide detailed information on the basic biology of *P. chapmani*. Answers to key questions (such as how many mice live in a mound, and what are the home ranges and spatial separation between mound populations) were seen as vital pre-requisites to the development of a successful translocation program (Nielsen , 1988). In 1994, Hamersley's research program shifted away from dedicated range and distribution surveys to studies that focused on the social structure and patterns of movement of *P. chapmani*.

Within suitable habitats, *P. chapmani* mounds can be found in very high densities (Fig 2). More importantly not all of the mounds within a particular area are occupied at the same time. Trapping of the mound is the most conclusive means of determining if a mound is occupied by mice. However trapping is a time-consuming process requiring several nights of effort. Because of this, an alternative method was developed to test for the presence of *P. chapmani* in a mound. The system used the external features of the pebble mound to determine if the mound was occupied by *P. chapmani* (Anstee, 1996). The scoring system proved to be an effective predictor of the presence of *P. chapmani* with active mounds having a significantly higher score than inactive mounds. More importantly it proved to be an effective way of assessing the status of a large number of mounds in a very short time.

Results of an intensive trapping and radio tracking program at Marandoo (Anstee *et al.*, 1997) and Yandi in 1997, indicated that pebble mounds represent an important resource in the life history of *P. chapmani*, forming the focal point of male and female home ranges with mice showing long term site fidelity towards home mounds. Populations within a single mound were often large and demographically complex (Anstee *et al.*, 1997).

The size and overlap of home-ranges and core areas have important implications for management programs directed at *P. chapmani*. In addition, the high level of social complexity indicates that management policies should be directed at the level of the social group rather than at the level of the individual. In order to increase the likelihood of a translocation being successful, translocations should involve the movement of entire mound groups rather than groups made up of individuals that are unknown to each other.

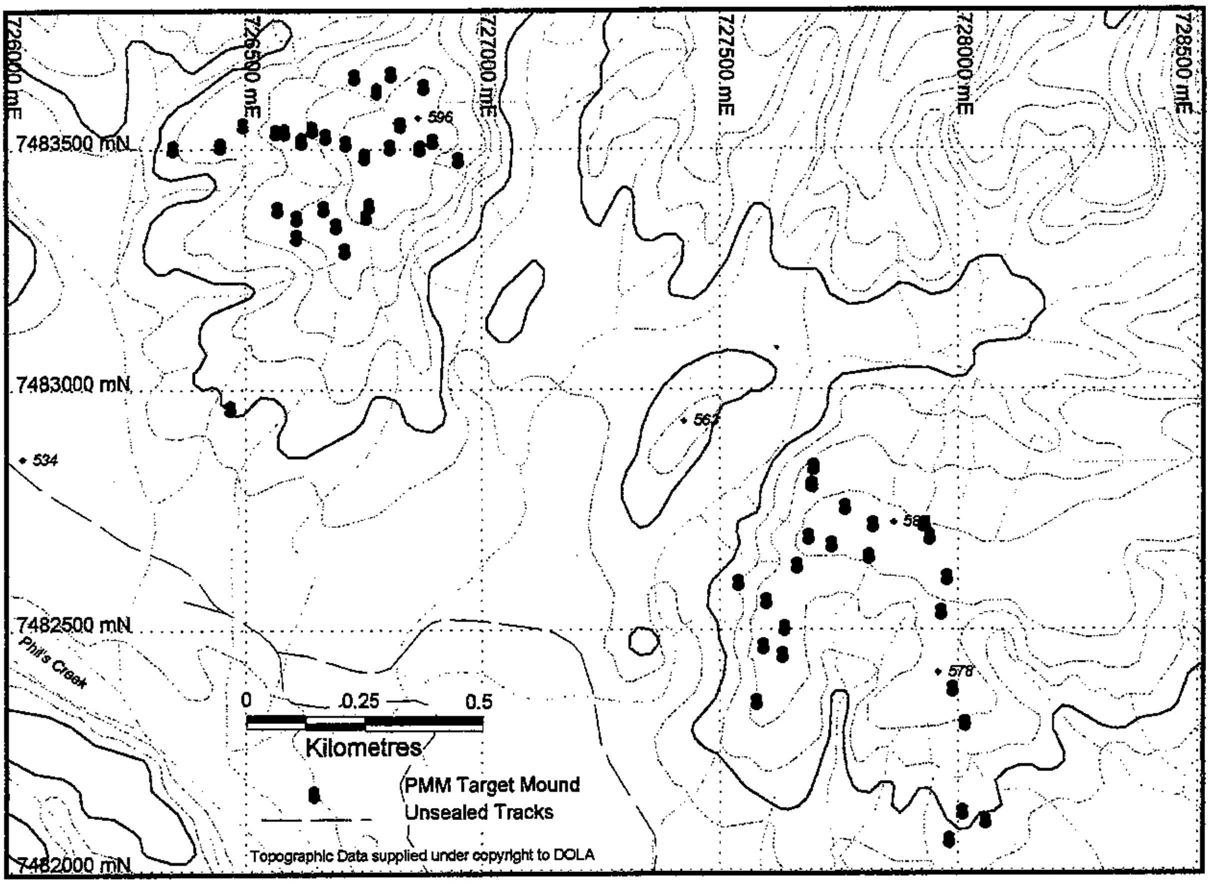


Fig. 2. Distribution and density of *Pseudomys chapmani* mounds on two hill tops within the Yandi study area.

TRANSLOCATION STUDY

The corner stone of the *P. chapmani* research program was the translocation study conducted at Hamersley's Yandi project. Detailed as part of the Yandi Environmental Management Program, the translocation study was designed to remove *P. chapmani* from areas that were to be disturbed by the project development and then relocated to an area close to Yandi that would not be disturbed. In addition to its primary role of removing mice from areas that were to be disturbed, the study was designed to test the effect of familiarity between individuals within founder groups on translocation success.

Work commenced in July 1997 to clear mice from active mounds within the proposed Yandi Project area. Volunteers from the Australian Trust for Conservation Volunteers and post graduate students from the University of Western Australia played an important role during this phase of the study. Mice were collected from a total of 45 mounds over a 1 month period. All mice captured during this period were transported to the Rhodes Ridge camp where they were allocated to one of three founder group treatments (Table 2).

Table 2. The level of individual and mound structure familiarity associated the three founder groups T1 -T3 and the control group T4. Each of the founder groups was replicated four time.

Treatment	Between individuals familiarity	Mound structure familiarity
T1 Unrelated away	All individual unfamiliar with each other.	All mice unfamiliar with the structure of the mound
T2 Related away	All individuals familiar with each other.	All mice unfamiliar with the structure of the mound
T3 Related at home	All individual familiar with each other.	All mice familiar with the structure of the mound
T4 Resident mice	All individual familiar with each other, but not part of founder group.	All mice familiar with the structure of the mound, but not part of founder group.

All the translocation groups were released onto their target mounds during the evening of the 9th of September 1997. The progress of the translocation groups within the mound enclosures was monitored for 7 nights following the release until it was concluded that the mice were utilising the underground burrows of their relocation mounds. The progress of the translocation groups was then monitored through a combination of radio tracking and trapping over an eight month period.

The success of the translocation was assessed by comparing the long term presence, fecundity and site fidelity of resident and translocated mice. Post release monitoring indicates that the translocation has indeed been very successful. Of the 101 *P. chapmani* translocated, 65% were recaptured in the study area post release, with the translocated mice showing similar rates of population decline as populations elsewhere in the Pilbara.

In addition the translocation appears to have had no effect on the reproductive activity of the translocated mice with reproductively active individuals being recorded in each of the four post release monitoring periods. Finally a comparison of distances moved between translocated and resident mice indicated that the translocated population was behaving in a similar manner to the resident group. From these results we have been able to conclude that a correctly structured translocation program is an effective management tool for dealing with *P. chapmani* in areas that are to be disturbed by mining.

REVIEW OF CONSERVATION STATUS

A review was conducted in 1996 by scientists from the Department of Conservation and Land Management (CALM) on the conservation status of *P. chapmani* (Start 1996). The review utilised data from a number of sources, but was particularly reliant on data collected by mining companies. The data indicated that the range of *P. chapmani* had declined over the past 50 years, with the biggest contractions occurring in the Gascoyne and west Pilbara. While there are a number of possible causes of this decline a strong association was found to exist between the loss of *P. chapmani* and the presence of foxes in that area.

The absence of foxes from the Central Pilbara, together with a large and well distributed *P. chapmani* population led Start (1996) to conclude that within suitable Pilbara habitats *P. chapmani* is common, widespread and secure. Start recommended that *P. chapmani* be deleted from the schedule of species declared to be "fauna that is likely to become extinct or is rare" under the western Australian Wildlife Conservation Act. Instead *P. chapmani* should be listed as a Priority 4 species on the CALM reserve list, and monitored to ensure that the factors that caused extinction in the Gascoyne and west Pilbara do not occur in its present range.

REFERENCES

Anstee, S. D. (1996). The use of external mound structure as an indicator of the presence of the Pebble Mound Mouse (*Pseudomys chapmani*) in mound systems. *Wildlife Research* **23:** 429-434.

Anstee, S. D., Roberts, J. D. and O'Shea, J. E. (1997). Observations on mound numbers and demographic structure of Pebble Mound Mouse (*Pseudomys chapmani*) mounds at Marandoo, Western Australia. *Wildlife Research* **24:** 295-305.

Dunlop, J. N. and Pound, I. R. (1981). Observations on the Pebble-mound mouse *Pseudomys chapmani* Kitchener, 1980. *Rec. West. Aust. Mus. 9*: 1-15.

Environment Australia (1998). Australia's National Report to the Fourth Conference of the Parties to the Convention on Biological Diversity.

Kitchener, D. J. (1980). A new species of *Pseudomys* (Rodentia: *Muridae*) from Western Australia. *Rec. West. Aust. Mus.* **8:** 405-414.

Nielsen, L. (1988). Definitions, considerations and guidelines for translocating wild animals. In 'Translocation of Wild Animals'. (Eds. L. Nielsen and R. D. Brown) *The Wisconsin Humane Society, Inc., and Caesar Kelberg Wildlife Research Institute.* Milwaukee. pp. 12-49.

Ninox, (1991). Marandoo Project: Vertebrate Fauna Assessments. Unpublished report for Hamersley Iron Pty Limited.

Piggott, M. S. (1992). Enviroscan Interim Report No 2. The Range and Distribution of the Pebble Mound Mouse: Gregory Range and Rudall River National Park. Unpublished report for Hamersley Iron Pty Limited.

Piggott, M. S. (1992b). Enviroscan Interim Report No 3. The Range and Distribution of the Pebble Mound Mouse. Unpublished report for Hamersley Iron Pty Limited.

Piggott, M. S. (1994). Enviroscan Technical Note. Range and Distribution of the Pebble Mound Mouse - West Pilbara. Unpublished report for Hamersley Iron Pty Limited.

Start A. N. (1996). A review of the conservation status of the Ngadji (Western Pebble Mound Mouse) *Pseudomys chapmani* Kitchener, 1980 (Rodentia muridae). Unpublished report to the Department of Conservation and Land Management Science and Information Division.

ORAL DELIVERY OF IMMUNOCONTRACEPTIVE ANTIGENS FOR FOXES IN AUSTRALIA

M.P. Bradley,[1] L. A. Hinds[2], and P. Bird[2]

[1]Perth Zoological Gardens, 20 Labouchere Rd, South Perth, WA 6151, Australia and the [2]Vertebrate Biocontrol Control Cooperative Research Centre, CSIRO Wildlife & Ecology, PO Box 84 Lyneham, ACT, 2602, Australia

SUMMARY

In Australia and New Zealand there are several major projects underway which are exploring the use of immunocontraceptive vaccines for the control of several vertebrate pest species. This work brings together an amalgam of diverse scientific disciplines ranging from reproductive biology and immunology to ecology. If these projects prove successful, fertility control for the management of feral animals is likely to become the practice of choice world-wide.

INTRODUCTION

Of all the exotic species introduced into Australia three probably have had the greatest impact; the European rabbit (*Oryctolagus cuniculus*), the European red fox (*Vulpes vulpes*) and the feral domestic cat (*Felis catus*). The fox and the cat, both predators, have found a ready food source in the small to medium-sized indigenous marsupials and rodents, thus leading to an extensive list of endangered and vulnerable species in Australia. Currently, fox predation is controlled primarily through the use of the poison '1080' delivered in suitable baits. This is an ongoing control measure and any reduction in this level of activity will inevitably lead to a rise in predator numbers. The long-term solution which is being proposed is to develop methods whereby the feral pests are maintained at low levels through the imposition of fertility control (Tyndale-Biscoe and Bradley, 1997). If successful, feral pest numbers will be reduced to a level where the impact of predation and habitat destruction is reduced, thus allowing the long term recovery and survival of a range of the native species.

In Europe, the red fox transmits parasitic diseases to pet dogs and people, and most importantly is the main vector for the spread of rabies (Artois *et al.*, 1993). Culling and vaccination are the current methods for fox rabies control, but wildlife managers are looking for additional means of controlling the spread of such diseases, and immunocontraception is now being considered a possibility. Preliminary modelling studies indicate that fertility control may have a role in the management of fox rabies by reducing the numbers of juvenile foxes which are difficult to reach by conventional vaccination. Immunocontraception therefore has the potential to reduce the annual birth rate in a permanent way providing a powerful tool to assist with overcoming these problems.

The Cooperative Research Centre for the Biological Control of Vertebrate Pest Populations was established in 1992 to investigate the use of immunocontraception for the control of feral pests in Australia. For fox control the initial aim is to develop a **bait-delivered** contraceptive vaccine. This approach is based on the success of vaccine delivery in baits for the control of rabies in Europe (Artois *et al.*, 1990) and has the potential to provide a very practical method for long-term fox management.

GAMETE ANTIGENS: THE TARGETS OF IMMUNOCONTRACEPTION

Research is now well advanced on the identification, cloning, expression and testing of a range of fox antigens, to evaluate their potential for use in an immunocontraceptive vaccine (Bradley, 1994; Bradley *et al.*, 1996; 1997; Beaton *et al.*, 1994, 1995). The focus of these studies now centres almost entirely on the use of the egg zona pellucida antigens. The zona pellucida of most species examined contains only three proteins, ZP1, ZP2 and ZP3. While these proteins all share regions of homology between species, the cloning of the genes which encode these proteins have revealed some differences in their amino acid sequences probably reflecting the species-specific functions of these proteins (Epifano & Dean, 1994). ZP3 has been identified as the primary protein to which sperm bind. Blocking the function of this protein with antibodies results in infertility (Epifano & Dean, 1994), and this has been experimentally demonstrated in a number of species. Therefore ZP3 can be considered an important protein target for immunocontraception. The gene which encodes the fox ZP3 protein has been cloned, and a recombinant protein has been produced in the baculovirus system in order to obtain glycosylated preparations of the antigens. Although it is recognised that the pattern of ZP glycosylation by baculovirus may not be identical to that of the native protein, studies indicate that ZP proteins produced in this system are antigenic and capable of producing antisera that block sperm-egg binding (Prasad *et al.*, 1995). Currently fertility trials with this recombinant antigen are in progress in both Australia and France.

ORAL VACCINE DELIVERY SYSTEMS

The delivery of an anti-fertility vaccine to wild animal populations over large areas raises a number of unique problems which require careful consideration. Parameters to consider include the distribution of the species under study, whether large scale or localised control is desired and the issue of directed specificity with regard to other species. Another factor that may need to be addressed is the administration of an immunocontraceptive vaccine to genetically heterogeneous wildlife populations in which significant variability in the immune responses to a vaccine exists between individuals. Effective application of a vaccine for fertility control requires that a high level of immunity be achieved amongst individuals exposed to the vaccine. It may therefore be necessary to include multiple antigenic determinants within a vaccine to stimulate a broad range of immune responses. In addition, the antigen(s) may need to be presented in conjunction with other highly immunogenic carrier proteins to maintain a contraceptive level of immunity.

A number of different vaccine delivery systems are being assessed to determine which will be the most effective for immunocontraception of animal populations. These include dart delivery, disseminating viral vectors and oral bait systems. For many species under consideration, bait delivery will be the best method of choice and this discussion will focus on bait delivery. Such a bait will need to be designed to be acceptable for the target species, and each bait will contain within it the contraceptive vaccine either as the recombinant protein or in the form of a microbial replicating vector which will infect the host, produce the recombinant antigen and stimulate the immune response.

The selection of the most appropriate delivery system for inclusion in a bait for example will be dependant on a number of factors such as the nature of the antigen to be included in the vector (ie glycosylated versus non-glycosylated), the safety of the delivery system, and the type of immune response the vector assists in inducing (Cryz, 1996). Some of the potential vectors are considered here.

Viral vectors

There are several different viral vectors currently being investigated for their potential as baited-vaccine delivery systems. These include poxviruses, adenoviruses and herpesviruses, with the poxviruses being the most thoroughly investigated to date. Vaccinia virus is the live poxvirus vaccine that has been used to eradicate smallpox. While it is neither an attenuated form of the variola virus that causes smallpox nor is it the cowpox virus, it is an orthopox virus whose origin and host is unknown (Smith, 1996). There have been many heterologous antigens expressed in vaccinia virus and its potential to induce both an antibody and a cell mediated immune response has been well documented. Since vaccinia virus caused some vaccination complications in some individuals there has been a concerted effort to produce an attenuated form of this virus for use as a vaccine delivery system for heterologous antigens (Smith, 1996).

The use of recombinant vaccinia viral vectors expressing genes encoding selected gamete antigens may offer an excellent delivery system for an immunocontraceptive vaccine, particularly for those antigens which are highly glycosylated, and in which post-translational modification is important for the generation of immune responses to functionally important domains. Such a system would also allow further studies on the enhancement of mucosal immunity possibly by constructing vectors that co-express IgA-specific stimulating cytokines (Ramsay *et al.*, 1994).

Bacterial vectors

There have been many bacterial species targeted for their potential as either vaccines or delivery systems for heterologous antigens (Cryz, 1996; Hodgson, 1994). These include both gram positive and gram negative strains with *Salmonella typhimurium* being the most extensively studied for its potential as a delivery vector. Considerable effort has resulted in the development of attenuated strains of *Salmonella* with the most common type in current usage being those strains which are deficient in one or more genes which are essential for the synthesis of aromatic amino acids and the regulation of cAMP. For example, the AroA mutants are auxotrophic for para-aminobenzoic acid and dihydroxybenzoate and these nutrients are not available in eukaryotes which means that the *Salmonella* are not able to grow in the host. While immunization of animals with Aro mutant strains have demonstrated no pathological consequences, it has resulted in a local secretory, humoral and cell-mediated response (Cryz, 1996). This suggests that *Salmonella* would be a useful delivery system for antigens targeting fertility.

Oral immunisation experiments with *Salmonella typhimurium* in foxes have demonstrated that immune responses to the *Salmonella* are of sufficient intensity and duration to warrant continuing work with *Salmonella* (de Jersey *et al.*, 1997). A *Salmonella typhimurium* recombinant expressing the fox LDH-C_4 antigen and delivered orally to foxes was capable of inducing a mucosal immune responses to the LDH-C_4 protein (Bird *et al*, 1997). Similarly *Salmonella typhimurium* expressing the human sperm SP10 antigen has induced antibodies in mice (Srinivasan *et al.*, 1995). Recombinant *Salmonella* expressing murine ZP3 have been constructed and oral immunisation of Balb/C mice induced significant anti-ZP3 IgG antibodies in serum and IgA antibodies in vaginal secretions with 3 out of the 6 females immunised being infertile (Zhang *et al.*, 1997).

Salmonella has the advantage in that it can be produced cheaply in large quantities using standard fermentation technology. Nevertheless, if *Salmonella* is used in a wildlife immunocontraceptive product it will be important that the bacteria are in a usable form. Freeze-dried salmonella would meet the criteria for field delivery. Initial studies with the oral delivery of freeze dried *Salmonella typhimurium* in to both mice and foxes indicate that both systemic and mucosal immune responses to the *Salmonella* (Bradley *et al.*, 1997) can be generated.

The requirements for environmental safety of a bait-delivered bacterial immunocontraceptive vaccine need to be addressed. One feature that would prevent any chance of foreign DNA getting into the environment would be a vaccine that does not contain any gamete DNA. One approach is to construct suicide plasmid systems which will destroy any gamete DNA before the vaccine is released into the environment. Initial *in vitro* tests show that such systems are feasible (personal communication)

Bacterial ghosts

Cloning and subsequent expression of the PhiX174 geneE in bacteria can result in the lysis of a variety of gram negative bacteria including *Escherichia coli, Salmonella typhimurium, Vibrio cholerae, Klebsiella pneumoniae* and *Actinobacillus*. This phage lysis results in a transmembrane tunnel through which the cytoplasmic contents of the bacteria are extruded yielding a non-living candidate vaccine delivery system - ghost bacteria which contain only membrane associated recombinant antigen. Recombinant bacterial ghosts are cheap to produce, can be stored for long periods and can contain multiple antigenic determinants that are present in a highly immunostimulatory environment (Szostak *et al.*, 1996). These features make bacterial ghosts an attractive delivery system for immunocontraceptive antigens. It remains to be determined whether these preparations produce immunity after oral delivery in foxes, but current studies underway in France, are assessing the potential of bacterial ghosts to deliver a ZP3 based vaccine to female foxes.

Synthetic delivery systems

While there has been much research directed at particulate delivery systems for parenteral vaccines, oral administration of vaccines is becoming increasingly desirable throughout the world and consequently there is growing research on oral particulate delivery systems. These systems include Iscoms (Quil A, Cholesterol, phospholipid constructs), microspheres (polylactide-coglycolide polyphosphazenes), and liposome emulsions (Davis, 1996) which all have potential as delivery systems for immunocontraceptive antigens. A study to evaluate the efficacy of microspheres containing a recombinant sperm antigen to stimulate a mucosal immune response in rats (Muir *et al.*, 1994) demonstrates the potential utility of these agents. Microspheres were synthesised using the poly-DL-lactide-co-glycolide co-polymer incorporating a recombinant source of the fox sperm protein FSA-1r (Beaton *et al.*, 1994). The oral administration of FSA-1r loaded microspheres to rats resulted in a significant production of cells within the jejunum that were secreting IgA antibodies specific for the FSA-1r antigen. The level of stimulation was comparable to that obtained by either direct immunisation of the Peyer's patches with microspheres containing antigen or unencapsulated antigen. However, the current cost of production would make these systems more suited to human and companion animal vaccination rather than broadscale application to a wildlife population. Nevertheless the per unit production cost will decrease as these systems become more popular and production technology improves.

CONCLUDING REMARKS

Based on current studies with ZP antigens, a bait delivered immunocontraceptive vaccine for the control of fox populations will most likely be comprised of these antigens delivered in a recombinant form either through the use of a non-disseminating virus (such as vaccinia), or as a recombinant bacterial product. Within the next 18 months evaluation studies with these products should determine which will be most suitable for limited field testing. Results from such large scale experiments will determine whether fertility control technologies will have application for the control of foxes within Australia's ecological landscapes.

Acknowledgements

This work was supported by Environment Australia, CSIRO Wildlife and Ecology, the CRC for the Biological Control of Vertebrate Pest Populations, and the Perth Zoological Gardens.

pp 191-195, 11th Australian Vertebrate Pest Conference, Bunbury, Western Australia, 3-8 May 1998. ISBN 1 86308 067 8.

REFERENCES

Artois, M., Masson, E., Barrat, J., and Aubert, M. Efficacy of three oral rabies vaccine baits in the red fox: a comparison. Vet. Microbiol. 38: 167-172 (1993)

Beaton, S, Cleary, A, ten Have, J, Bradley, MP Cloning and characterisation of a fox sperm protein FSA-1. Reprod. Fertil. Dev. 6: 761-770 (1994)

Beaton, S, ten Have, J, Cleary, A, Bradley, MP Cloning and partial characterisation of the cDNA encoding the fox sperm antigen FSA-Acr.1 with similarities to the SP-10 antigen. Mol. Reprod. Dev. 40: 242-252 (1995)

Bird, P.H., Hayes, C.M., and Bradley, M.P. Immunological assessment of *Salmonella typhimurium* recombinant vaccine expressing fox LDH-C4. Proceedings of the 4th International Conference on Fertility Control for Wildlife Management, p39, Great Keppel Island, Australia, 8-11th July (1996)

Bradley, M.P. Experimental strategies for the development of an immunocontraceptive vaccine for the european red fox *Vulpes vulpes*. Reprod. Fertil. Dev. 6: 307-317 (1994)

Bradley, M.P., Geelan, A., Leitch, V., and Goldberg, E. Cloning, sequencing and characterisation of LDH-C4 from a fox testis cDNA library. Mol. Reprod. & Devel. 44:452-459 (1996)

Bradley MP, Hinds, LA and Bird P.H. A bait-delivered immunocontraceptive vaccine for the European red fox Vulpes vulpes by the year 2002? Reprod. Fertil. Dev. 9:111-116 (1997)

Cryz jr., S.J. Vaccine delivery systems: Live attenuated bacterial vaccine vector systems. Vaccine 14: 676-80. (1996).

Davis., S.S. (1996). Vaccine delivery systems: Particulate delivery systems. Vaccine 14: 672-75.

de Jersey, J., Hinds, L.A. and Bradley, M.P. Regulation of reproductive tract immunoglobulins by oestrodial-17ß in the European red fox (*Vulpes vulpes*). Reprod. Fertil. and Development. 9: 531-538 (1997)

Epifano, O. and Dean, J. Biology and Structure of the Zona Pellucida: a target for immunocontraception. Reprod. Fertil. Dev. 6: 319-30 (1994)

Muir, W., Gipps, E., Husband, A. and Bradley, M. P. Intestinal vaccination using biodegradable microspheres. Immunology Letters 42: 203-7. (1994)

Prasad, SV, Mujtaba, S., Lee, VH, & Dunbar, BS. Immunogenicity enhancement of recombinant rabbit 55-kilodalton zona pellucida protein expressed using the baculovirus expression system. VBiol. Repord. 52: 1167-1178 (1995)

Ramsay, A.J., Leong, K-H., Boyle, D., Ruby, J. And Ramshaw, I.A. Enhancement of mucosal IgA responses by interleukins 5 and 6 encoded in recombinant vaccine vectors. Reprod. Fertil. Devel. 6: 389-392 (1994)

Smith, G.L. Vaccine delivery systems: Genetically engineered viruses as candidate vaccines. Vaccine 14: 681-83 (1996)

Szostak, M.P., Hensel, A., Eko, F.O., Klei, R., Auer, T., Mader, H., Haslberger, A., Bunka, S., Wanner, G. and Lubitz, W. (1996). Bacterial Ghosts: non-living candidate vaccines. J.of Biotechnol. 44: 161-70.

Tyndale-Biscoe, C.H. And Bradley, M.P. Vaccination for wildlife contraception. In: Veterinary Vaccinology. (Eds: Pastoret, P.-P; Blancou, J., Vannier, P., & Verschueren, C.) Elsevier Science B.V. Amsterdam. pp492-498 (1997).

Zhang, X., Lou, Y., Koopman, M., Doggett, T., Tung, K.S.K. and Curtiss III, R. . Antibody responses and infertility in mice following oral immunisation with attenuated *salmonella typhimurium* expressing recombinant murine ZP3. Biol Reprod. 56: 33-41 (1997)

Managing Marsupial Breeding as a Conservation Tool

John Rodger
Director Cooperative Research Centre for Conservation & Management of Marsupials

The Marsupial CRC is joint venture between: Perth Zoo, Landcare Research (NZ), University of Newcastle, Macquarie University, Qld Agricultural Biotechnology Centre (Qld DPI). **Supported by:** Environment ACT, University of Western Sydney, Boyce Thompson Institute for Plant Research (USA).

THE NEED TO MANAGE BREEDING FOR CONSERVATION

Managing the reproduction of wild species, such as marsupials, has two basic goals:

ï **Increased production of young**
ï **Decreased production of young**

Just as with human reproduction the aim for some individuals is to have young and for others the aim is to not. In a conservation context this means managing fertility and productivity for the preservation or enhancement of biodiversity.

Reproductive biology and reproductive technologies have roles in three main areas:

1. Diagnosis of reproductive status and fertility

In many captive breeding situations, or even in small or isolated populations of endangered animals there can be failure of breeding generally or of some individuals. But why ?

Basic issues that reproductive biologists can address include:

ï Is there some reproductive pathology eg. Are the males producing sperm and are the sperm normal.

ï Are the females undergoing reproductive cycles. If not why not.

ï Are the animals mating Are matings leading to conception.

ï To what extent is the species a seasonal breeder

ï Does the species have multiple cycles per year or only one

ï What induces the female to cycle

ï What are the dynamics of reproductive behaviour

2. Assisted Reproductive Technology (ART)

There has been amazing developments in our ability to manipulate the fertility of humans, lab animals and domestic species but is this if relevance to conservation? In the past there has been a fairly uncritical approach by many advocates of ART for conservation and in the earlier years some fairly major failures to deliver. The main issue is to fit the appropriate technology to the problem in hand. There is no point in attempting to apply a very complex technical solution to a problem solved in a much simpler way. However, sometimes more technical approaches may be the only long term option provided some of the basic reproductive information listed above is available. A reason for many of the early failures to effectively apply ART to conservation was the assumption that ideas developed in domestic animals and humans could be easily transferred to other species.

Examples of problems where reproductive technologies can be applied

ï When animals with desired genetic constitution fail to breed. Often relatively simple technology such as monitoring hormonal cycles (preferably in faeces or urine) and then introduction of males at the appropriate time can yield positive results.

ï A somewhat more complex solution may be to use artificial insemination. Although, more technically complex this is a relatively straightforward procedure applicable to very many species.

ï Storing semen. Often there is a need to preserve genetic material for long periods especially if a very valuable animal is aging. Semen collection and freezing are technologies again which are broadly applicable to a many species.

ï In the longer term as technologies such as egg freezing, egg culture and IVF are better refined there is every likelihood that such quite high technology ART may also have application in some conservation programs for very valuable species with intractable conservation management problems.

A key element in most of this work is managing the reproductive cycle of the female. This can in many cases be done by simply monitoring hormones. However, knowledge of the basic mechanisms underlying the control of the female cycle is rapidly expanding and in the longer term the use of hormones to induce breeding and support pregnancy can also be expected to have application in conservation breeding.

3. Control of overabundant animals - introduced pest species and native species

Traditionally such animals have been killed. Considerable work is going on in Australia and around the world to develop fertility control technologies suitable for the management of such populations. A copy of a paper discussing this issue and the current state of technology development is attached.

MANAGING MARSUPIAL FERTILITY

John Rodger, Cooperative Research Centre for Conservation and Management.
Marsupial CRC PO Box 1927, Macquarie Centre NSW 2113. Australia.
E-Mail: jrodger@possum.bio.mq.edu.au

The Need to Manage Marsupial Populations

Overabundance of wild species has traditionally been seen as a pest management issue arising from some demonstrated or perceived economic impact. The situation is more complex and questions of overabundance may also have direct and indirect impacts on conservation. These impacts may be due to: 1) An introduced pest which has negative effects on habitat or direct impacts on native species as well as impacts on agriculture; 2) An abundant native species which impacts on habitat quality and thus like introduced pests also threatens endangered species or communities; 3) An abundant native species which threatens its own survival by habitat destruction; 4.) Removal of animal and human predators and 'improvement' of habitat by human activities which have altered the normal population equilibrium. Managing abundance can no longer be seen as a simple 'good' native animal versus bad 'introduced pest' dichotomy. Further, even with an unequivocal pest, management decisions are not clear cut; one country's pest management should not threaten another's biodiversity. In addition, over abundance may lead to undesirable animal welfare impacts. Thus wildlife managers must increasingly include a broad spectrum of issues in their decision making but they have few, and relatively old tools, to apply to population management.

Case 1: Introduced marsupial pests

The case for control of the common brushtail possum in New Zealand an introduced marsupial pest which destroys habitat, predates on native species and is the major vector for bovine tuberculosis is well established and animal health and conservation agencies are involved in control activities to reduce pest numbers.

Case 2: Abundant native species which threaten endangered species or communities

In Australia the best example of this type of impact are the abundant large kangaroos. In particular the grey kangaroos which reach very high densities in temperate woodlands of the ACT or in more arid regions where densities are relative low yet the impact of grazing is great such as is western Victoria or the north of South Australia. For a variety of reasons density of these species can rise to levels with deleterious impacts on the environment. The environmental effects in this case are effectively the same as introduced pests and thus the rationale for control is the same, although the criteria for effective control are very different.

Case 3: Abundant native species which threatens its own habitat

An example of this type of situation are certain koala populations in South Australia and western Victoria. Here as a result presumably of reduced natural and human predation populations have grown well beyond the sustainable carrying capacity. Since the end of koala economic exploitation early in the century there have been several examples of koala colonies eating their entire food resource with catastrophic results. Such situations may have conservation impacts or may mainly raise animal welfare concerns.

Case 4: Abundance due to human interference
A problem in lay perception of these issues of management of abundance is a notion that the current situation is natural and that 'natural' processes will return populations to a sustainable level. Unfortunately there is clear evidence that current situations often do not represent natural equilibria. In Australia there is the further complication that conditions are not stable so the notion of a correct population density for a species is in most cases a nonsense because conditions and animal densities can fluctuate significantly. However, we do know that human activity has drastically altered habitats and these can lead to abundance. The high numbers of kangaroos in the ACT are presumably a result of removal of natural predators and increased grassland.

The importance of Aboriginal impacts on wildlife numbers has been recognised for some time but only more recently has it been argued seriously that the impacts of such practices may need to be restored, albeit in a very different context. Perhaps the best example of the effects of Aboriginal activity on wildlife density in Australia is the koala. Koala densities at the time of European settlement were very low presumably due to Aboriginal hunting. However, this Aboriginal impact was removed and koala numbers rose to such a level that by the late 18th century a large commercial industry was sustained on their skins.

Current Population Control Technologies
Existing population control technologies for vertebrates including marsupials are predominantly lethal technologies based on the use of chemical toxins and traps. To a lesser extent exclusion of pest species by barriers such as fences are also used. Target specificity is a problem with all technologies and especially toxins. All currently used toxins are non-specific and considerable efforts are made to ensure that non-target species uptake is minimised by the method of delivery.

In a limited number of cases species-specific biological control is also available such as myxoma and calicivirus for rabbits but again these are lethal technologies. All lethal technologies suffer from the adaptive evolutionary drive they generate. Inevitably it is those animals that survive, or avoid, the control strategy, which reproduce. The development of resistance to myxoma in Australian wild rabbits being a classic example. Lethal technologies also raise serious animal welfare concerns. Changes in community attitudes means that any new lethal technology must now be shown to acceptably balance effectiveness and humaneness. A major argument in favour of calicivirus as a control strategy for rabbits was that it lead to a faster and apparently more humane death for the infected rabbit.

New and Emerging Population Management Technologies
Controlling the fertility of wild populations as a means to reduce numbers is a recently developed concept. Control of vertebrate fertility through use of hormonal manipulation as in the human birth control pill has been possible for decades but the problems of application in the field, species-specificity and disruption of normal behaviour have not been resolved. Over the last decade there has been a growing interest in the feasibility of using contraceptive vaccines to control fertility of wild animals delivered either as an oral bait or through a biological vector such as a virus. Such an approach addresses the issues of animal welfare, arguably may improve specificity and since it is non-lethal may drive evolution less strongly. However, such technology is only at the early development stage and its effectiveness in free ranging populations is yet to be demonstrated. In addition as genetic technology, and even the release of genetically modified organisms may be involved there are many questions of environmental risk and public perception of risk which remain to be resolved.

Four Key Questions for Immuno-contraception of Marsupials

1. What percentage of a population must be sterile to induce negative growth?
In New Zealand work is underway to examine the effects of surgical sterilisation by vasectomy and oviduct ligation on populations of possums. These studies will define the percentage of the population, both male and female, which must be sterilised to effect a decline in population. Modelling of immunocontraceptive based possum control spread by a sexually transmitted virus suggests that populations would decline significantly if the female was targeted and greater than 75% of the population were sterilised.

2. Can a species-specific antifertility vaccine be developed that is long acting and effective after a single exposure?
Many of the candidate antigens currently under investigation are not unique to the target species although portions of the molecules are species-specific. Thus species-specificity of the contractive vaccine remains feasible. The likelihood of a single exposure being an effective immunisation remains problematical and in deed the need for this criteria will depend on the species and the characteristics of the vector.

A key issue to be resolved here is to what extent reproductive antigens are seen as self-antigens and thus weak immunogens in contrast to microbiological antigens which in general are strong immunogens. Several critics have flagged this issue but although immunogenicity is likely to remain a key question it is clear from the many cases of human infertility that sperm antigens can induce a contraceptive immunological effect in both males and females. Similarly active immunisation with whole gametes or gamete extracts can lead to immunocontraception in a range of animals including the possum. Presumably the reasons for this immunity are that sex specific products are usually not normally seen by the immune system of the other gender. Or alternatively since they only appear at puberty they were not present at the time of establishment of self-recognition.

3. Can a delivery system be developed which will reach the required proportion of the population?
In the case of the rabbit, myxoma virus is a strong candidate as such a vaccine delivery system. Much is known of its characteristics, molecular biology and the epidemiology of myxomatosis outbreaks. For the only marsupial management problem where viral delivery is suggested, the possum in New Zealand, no candidate disseminating vector is available. Bait delivery is likely to have application for enclosed populations and for controlling locally abundant species such as the eastern grey kangaroo. However, it is unlikely to be an effective long-term strategy for widely distributed animals like the possum. The mass production of antigens by bacterial or other expression systems for delivery in baits is reasonably well understood and much is known about improving the optimisation of delivery to target species and minimising impacts on non-target species thus the strategy can be expected to be technically feasible.

4. What are the risks and costs?
In the case of a virus vectored system the main concern centres around the non-recallability of the engineered virus and any as yet unidentified undesirable effect that it might have. In Australia and new Zealand such issues are under the supervision of a national authority which monitors all work with genetically modified organisms and release would require a step wise approval process from the laboratory via experiments in high security animal facilities prior to release initially probably on an isolated island.

Cost of any biocontrol system will be a vital factor in whether it is employed. The major problem with bait based strategies will be the cost of distribution. Certainly for possums in New Zealand a fertility control system delivered by bait is unlikely to be cost effective compared with toxins. Yet and integrated program of fertility control after toxin control may be an effective method to reduce the frequency of toxin control and thus cost saving. However, community attitudes and animal welfare considerations may out way a simple cost comparison.

What then is the current state of play?
Research in Australia and New Zealand is testing in the laboratory and field the many components of the immuno-contraceptive concept for wild populations. Sperm and egg antigens are being characterised for a range of marsupials including the main target species under discussion and some of these are species-specific or at least the epitopes recognised for identification were species-specific. Considerable work in many fields is examining improved gene expression systems to produce high quality proteins with the desired properties. Finally oral immunization technology is advancing rapidly and even if distribution remains a major limitation oral immunization is likely to be feasible in the short to medium term and it will have application for certain species in defined situations and is likely to be the first form in which immunocontraception will be trialed in the wild. It is a very brave prophet who would say any particular hypothetical biotechnology is impossible. Vaccine development using genetically engineered antigens is a very dynamic field. Recently it has been demonstrated that genetically engineered potatoes can be used to produce an orally effective vaccination against *E. coli*.

Conclusion
Increasingly wildlife mangers have to manage introduced pests and abundant native species as well as the rare and endangered. Managers face these complex technical questions often with inadequate information and limited tools. Public interest is strong, and generally supportive, although not always based in an understanding of the basic principles of ecology. In addition, public opinion is demanding that non-lethal fertility based methods of population control should be used to manage abundance even of pests. However, such fertility control tools are not yet available and their safety and efficacy is yet to be established.

It is an enormous technical challenge to develop biological control for widely distributed wild populations. When its is added to this technical problem that it must be nationally and internationally environmentally benign, be specific and act in a manner which is acceptable on animal welfare grounds the task would seem insurmountable. However, the stakes are very high wildlife abundance is an increasing problem world wide and their health, agricultural and environmental impacts are increasing. However, the very scale of the challenge may be the catalyst to its solution as scientists and research funders become increasing aware of the need to build multidisciplinary teams to tackle these most important and exciting fundamental and practical questions which extend cutting edge molecular, cellular, whole organism and population biology from the laboratory to the wild.