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*M.P.J.*

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**ASPECTS OF THE ECOLOGY  
OF THE GREATER BILBY,  
*MACROTIS LAGOTIS*,  
IN QUEENSLAND.**



*Rob and I worked many days in the field and had many long and interesting conversations about the bilby and the environment.*

**Peter Donald McRae B. Sc.**

**A thesis submitted in fulfilment of the requirements for the  
degree of Master of Science**

**School of Biological Sciences  
University of Sydney  
August 2004**

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### ***Dedication***

*This thesis is dedicated to the late Rob Atherton and recently retired Greg Gordon, two dear and dedicated colleagues and friends, who introduced me to bilbies and work in the expansive and romantic channel country of western Queensland in 1988.*

*Rob and I shared many days in the field and had many long and treasured conversations about bilbies, conservation, humanity and the universe.*

*Thanks Guys.*

## DECLARATION

The work described in this thesis is original, except where acknowledged, and has not been submitted for a higher degree at another university.

A handwritten signature in black ink, appearing to read "Peter McRae". The signature is written in a cursive style with a large initial 'P' and 'M'.

Peter D. McRae



## ABSTRACT

The greater bilby *Macrotis lagotis*, an omnivorous marsupial bandicoot once occurred over 70% of the Australian mainland. It has suffered a major decline in range over the past 200 years. The decline in Queensland has been most dramatic.

This thesis examines some previously unreported aspects of the ecology and natural history of the bilby from a wild population in far western Queensland's arid zone, and identifies and explains the current range of the species in an historical context. Aspects of the ecology of the bilby were conducted within Astrebla Downs National Park (170 000 ha.).

Examination of the spatial distribution of burrows and their use by bilbies was hampered by the trappability of individuals since they could not be captured using standard wire cage traps. Instead, individuals were located by spotlight at night and then followed to a burrow where a 'fence trap', incorporating cage traps in the fence perimeter, was constructed around the burrow. A majority of individuals (63% of females, 71% of males) did not use the burrow at the site of trapping again. There was a significant impact of trapping on the post-trap movements made by both sexes for the first 2 days after trapping.

*M. lagotis* is sexually dimorphic for body size: male  $1095 \pm 39$  g, female  $824 \pm 18$  g; the means of pes length, head length, head width and canine width were significantly larger in males. Mean body temperature was  $35.6 \pm 0.2$  °C. Females commenced breeding at 6 months of age and continued to breed throughout the year, producing on average two young at a time.

Burrows provided the best visible evidence of bilby presence in an area. These were nearly always accompanied by distinct feeding scrapes, 5-25 cm deep, generally concentrated within 5 m of the burrow. Eighty four percent of 1475 burrows examined had a single entrance, and 50% of these were less than 2.5 m in diameter. Burrow temperature at 1 m depth revealed a remarkably stable burrow thermal environment, where the temperature was maintained between 19-26 °C even though daily ambient temperature ranged between 4-27 °C (winter) and 18-40 °C (summer).

The number of burrows used by individuals was significantly different between sexes; males used a mean of 7.2 burrows and females 3.6, during 30 days of telemetry locations.

Mean burrow ranges for males,  $15.3 \pm 4.6$  ha, were larger than those of females,  $3.0 \pm 0.8$ . Mean home range sizes were also significantly greater: 51.3 Ha males vs. 20.3 ha females. The mean distance between the individual burrows used by males was 435 m, and 188 m for females. The maximum nightly foraging movement recorded was 4.6 km for a male, and 2.2 km for a female.

An understanding of the spatial distribution of burrows and their use by bilbies facilitated the development of aerial survey techniques that allowed monitoring of relative changes in bilby population density over time. Broadscale aerial surveys of bilby burrows were conducted throughout the species' current known range in Queensland in 1994 and 1999. The surveys were conducted over an area of approximately 87 000 km<sup>2</sup>.

Overall burrow densities observed were low, and populations were fragmented. The largest burrow densities occurred in ashy clay plains. Core burrow areas (where the burrow density was  $> 4 \text{ km}^{-2}$ ) declined between 1994 and 1999. Total bilby population estimates doubled during the same period, but core areas contracted and now 65% of core areas of bilbies now occur only within Astrebla Downs National Park. The contraction in core burrow areas exposes two isolated populations of bilbies to the threat of local extinction.

Historical range decline was attributed to a wide range of human and landscape factors including loss of habitat and the introduction of exotic predators and competitors in eastern areas of the State.

Introduced predators present the greatest threat to extant populations of *M. lagotis* in Queensland. This threat is being exacerbated by the expansion of artificial water in the region.

## ACKNOWLEDGEMENTS

One can never take enough time to thank all those involved in seeing this project come to fruition. It is worth taking up as much space as it takes, at the beginning of this thesis, to thank all of those people who have contributed in a multitude of ways to what follows. They all helped in varying ways and shoulder no responsibility for what or how I say what is contained in this thesis.

I am afforded the illustrious distinction of being the last of Professor Ian Hume's postgraduate students. It is an honour. Ian, a wonderful and caring human being provided the impetus for me to get off my arse and write down some of the many things I had been doing over a long period of time. He convinced Professor Chris Dickman to share the responsibility. Chris, an unassuming and brilliant ecologist, perhaps the busiest person I have ever met who doesn't show it, saw me through to the end. Both had concerns along the way with my writing skills but particularly my time management. A big thanks to two wonderful human beings.

Greg Gordon inspired me from the outset with his softly spoken and quiet manner, and it is as result of him that my love of the channel country and all it has to offer is still very much alive.

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# CHAPTER 1

## *INTRODUCTION AND STUDY AREA*

---

### 1.0 INTRODUCTION

This study has described part of a long-term study investigating the conservation status of the bilby *Macrotis lagotis* in Queensland by the Queensland National Parks and Wildlife Service. The Parks and Wildlife Service raised concerns as a result of the lack of bilby records obtained during the course of the Diamantina Shire fauna survey, which was extensive in area, intensive in effort, and conducted over a period of 5 years between 1981 and 1985. A total of 803 person /field days were spent in the field during 11 separate visits during this period and 7 921 faunal observations were recorded. Search effort (for all species) included 290 hours of spotlighting from vehicles, 130 hours spotlighting on foot, 39 580 trap nights with small Elliott traps and 7 580 trap nights with bandicoot traps (R. Atherton *et al.* unpublished). Despite this intensive effort and a special effort directed at threatened vertebrates, bilbies were recorded from only nine sites on six properties within the 94 690 km<sup>2</sup> shire. These observations involved sign only i.e. scratchings and burrows that were attributed to the species. No live animals were seen or trapped (R. Atherton *et al.* unpublished). At the same time (1983-1985) Rick Southgate from the Northern Territory Conservation Commission was conducting an investigation into the distribution and status of the species throughout Australia. His work indicated the presence of isolated and widely scattered, low-density populations in far southwestern Queensland. Further, he considered the Queensland population to be the most vulnerable in the broad Australian context (Southgate 1987).

This thesis aims to determine the current distribution and abundance of the bilby in Queensland and discuss the reasons for the historical declines. Aspects of the biology and ecology of bilbies are investigated as part of these aims.

## 1.1 DESCRIPTION OF THE ANIMAL

The often-quoted words of Hedley Finlayson (1935a) stand unsurpassed in describing this beautiful and unusual animal:

*"Remarkable amongst the smaller forms is the talgoo, one of the so-called rabbit bandicoots, which has carried a number of structural peculiarities to grotesque lengths yet manages to reconcile them all in a surprisingly harmonious, and even beautiful whole.*

*The coat is one of the most beautiful amongst the marsupials: fine, silky, slate-blue, and quite like chinchilla. But the general aspect of the animal recalls a miniature aard-vark and it resembles that African animal in being a most powerful burrower."*

The bilby is a morphologically curious and distinct marsupial omnivore belonging to the family Peramelidae (sub family Thylacomyinae Strahan (1995)). (See Plates 1.1 and 1.2). A number of authors have reported on various aspects of the biology and ecology of the species. Reviews of the taxonomic history of the species have been provided by Johnson (1989), Southgate (1990a) and Gibson (1999). Wood Jones (1924), Troughton (1932) and Johnson (1983, 1989) provided morphological descriptions of the species. McCracken (1986, 1990) reported on reproductive biology and skeletal morphology, and Smyth and Philpott (1968), Watts (1969) and Southgate (1990b, 1990c) on aspects of habitat utilization, diet and natural history. Southgate and Abbot (1993) and Moritz *et al.* (1997) reported on population genetics and Gibson and Hume examined the nutritional ecology and ecophysiology of the species (Gibson 2001, Gibson and Hume 2000a, 2000b, 2002, Gibson *et al.* 2002).

Distinguishing features of the species include a long pointed snout and large naked ears. The bilby is strictly nocturnal and seeks shelter by day in a deeply excavated burrow. It digs for the majority of its food, leaving occupied areas littered with shallow conical excavations or 'feed scrapes' as evidence of nightly foraging.

For an overall review of the Thylacomyidae (prior to incorporation of the family within Peramelidae) see Johnson (1989). In many respects of lifestyle and form the bilby could be regarded as our native rabbit.



**Plate 1.1** Adult female *Macrotis lagotis*



**Plate 1.2** Adult female *Macrotis lagotis*

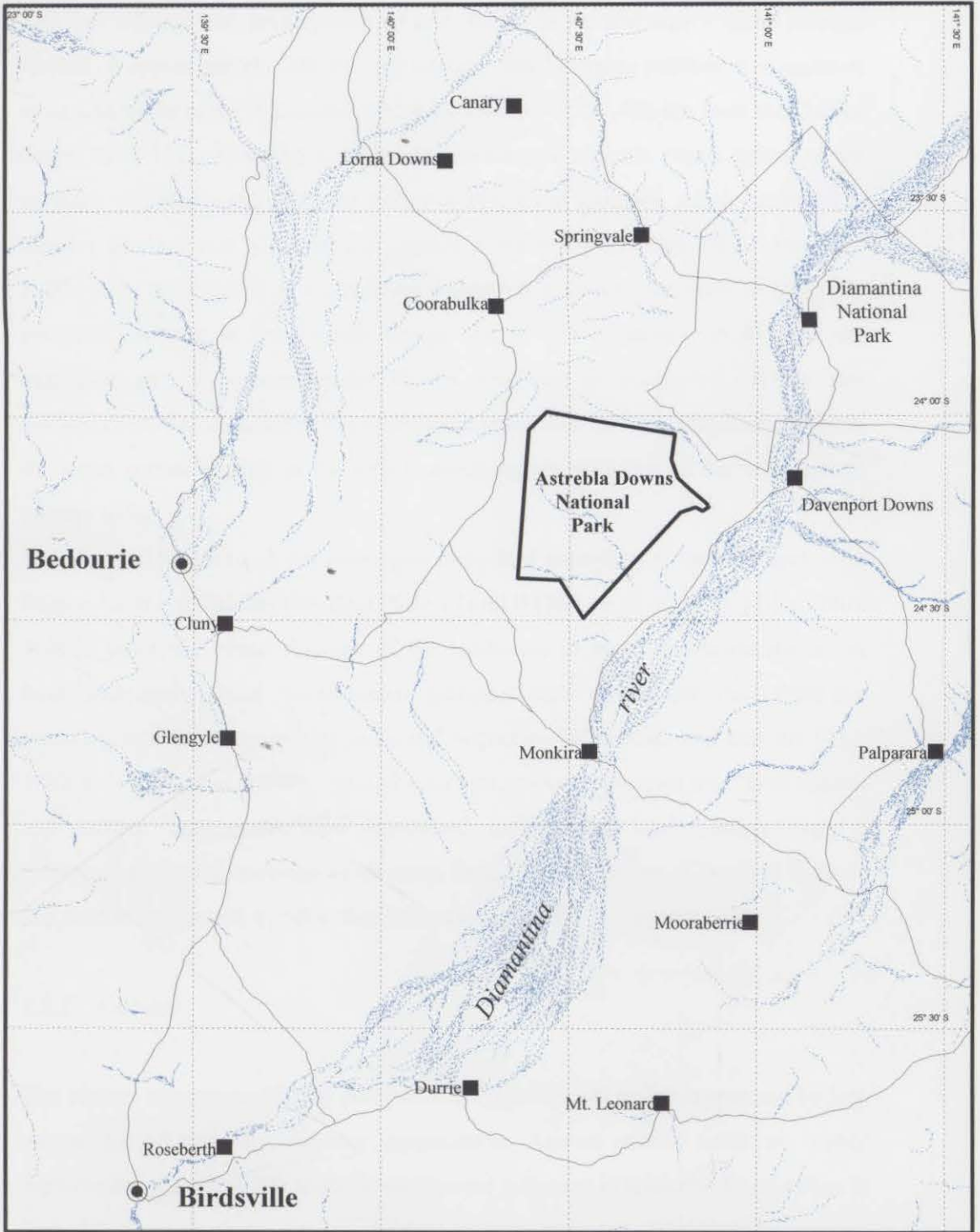
It shares with the rabbit a high reproductive potential, a semi-fossorial existence and broad habitat preferences. Unfortunately it has shown an inability to successfully share habitat with the rabbit or to tolerate the depredations of the European red fox *Vulpes vulpes* that successfully followed the rabbit invasion through much of inland Australia. (Southgate 1990b; Saunders *et al.* 1995).

## 1.2 STUDY AREA

The study area encompassed an area of 87,010 km<sup>2</sup> in the channel country of far southwestern Queensland between latitudes 23° S and 26° S and longitudes 139° E and 141.6° E. It included the small western towns of Birdsville, Bedourie and Betoota (Fig 1.1). The extensive drainage systems of Eyre Creek, the Diamantina River and Farrah's Creek and the undulating plains and dune-fields between these systems are the dominant natural features of the area.

### 1.2.1 Physiography

The two major drainage systems that occur in the study area are the Diamantina system to the east and the Georgina system in the west. The extensive catchment areas for both of these systems lie to the northeast and northwest of the study area respectively. The Georgina system consists of a complex of drainage systems of the Mulligan, Georgina, Burke and Hamilton rivers, which all eventually drain into Eyre Creek on the eastern edge of the Simpson Desert and subsequently south to Lake Eyre in South Australia. The Diamantina system consists of the Diamantina and Mayne rivers. Both systems have extensive feeder creeks throughout their lengths. These two systems and the Cooper Creek system further to the east constitute what is termed the Channel Country, which is characterised by an extensive network of anastomosing channels and braided creeks, which make up the channel country. A major characteristic of this drainage pattern is that the catchments lie hundreds of kilometres to the north in areas of much higher rainfall.



**Fig 1. 1** Location of the study area



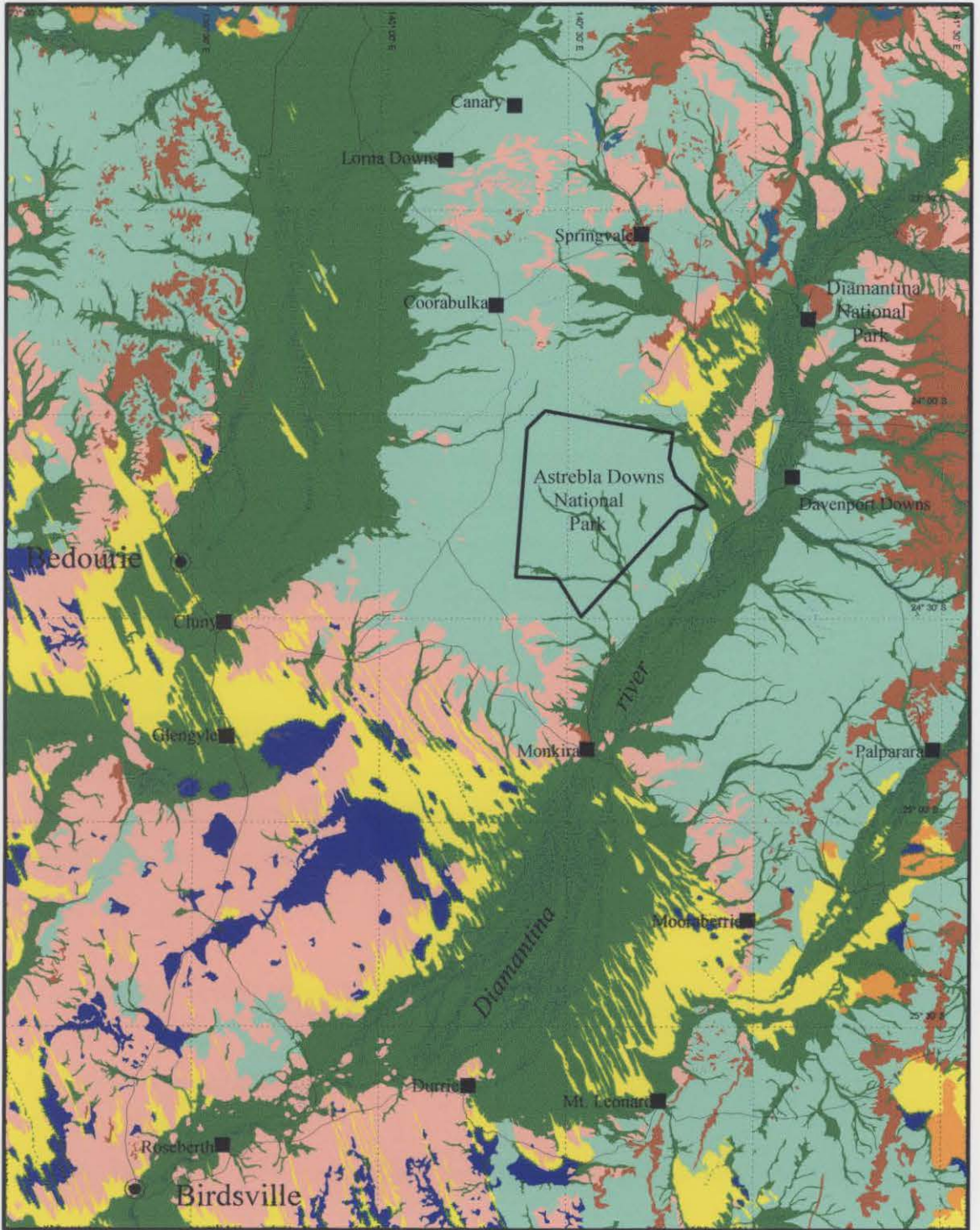
This has allowed the development of pastoralism in an arid area with an average rainfall of approximately 200 mm per annum. The Georgina catchment is centered in an area to the north of Cammoweal, which is only 300 – 400 km from the Gulf of Carpentaria. This catchment is exposed to monsoonal climatic events typical of the northern gulf region including the influence of tropical cyclones, which can result in massive rainfalls that will eventually result in water flowing into Lake Eyre, some 1000 km to the south. The Diamantina watershed is also to the north of the study area and centered in the Swords Range area to the southwest of Kynuna and extending east to approximately 50 km southeast of Richmond. Whilst this catchment isn't as exposed to the monsoonal influences as the Georgina catchment, the mean annual rainfall in the area is much higher than that of the arid channel country to the south.

The physical features of the area were described according to the Western Arid Region Land Use Studies (Warlus) Parts VI and II (Wilson *et al.* 1990, Mills 1980). Warlus described broad features of the landscape in terms of 'landsystems'. A landsystem was defined "as an area or groups of areas throughout which there is a recurring pattern of topography, soils and vegetation" (Christian and Stewart 1953; 1968 in Wilson *et al.* 1990). Similar land systems were grouped into 'land zones', and smaller 'land units' were recognised within these land systems. Fig 1.2 illustrates land zone coverage of the area. Detailed descriptions of the land systems and land units relevant to bilby distribution are provided in Appendix I.

### ***1.2.2 Climate***

The climate experienced in the study area is typically arid and characterised by low annual rainfall and high summer temperatures. Annual rainfall totals are highly variable and a marked late summer monsoonal influence is apparent. Evaporation is high. Daily temperatures are also marked by large seasonal and diurnal variability. Temperature and rainfall data characteristic of the study area are shown in Figures 1.3 and 1.4.

### ***1.2.3 Land use***



- |   |  |
|---|--|
| <span style="display: inline-block; width: 15px; height: 15px; background-color: yellow; border: 1px solid black; margin-right: 5px;"></span> Dunefields  | <span style="display: inline-block; width: 15px; height: 15px; background-color: darkblue; border: 1px solid black; margin-right: 5px;"></span> Seasonally dry lakes |
| <span style="display: inline-block; width: 15px; height: 15px; background-color: darkgreen; border: 1px solid black; margin-right: 5px;"></span> Channels, timbered drainage lines and alluvials                      | <span style="display: inline-block; width: 15px; height: 15px; background-color: brown; border: 1px solid black; margin-right: 5px;"></span> Residual stony hills    |
| <span style="display: inline-block; width: 15px; height: 15px; background-color: lightgreen; border: 1px solid black; margin-right: 5px;"></span> Flat to undulating plains dominated by mitchell grass and chenopods | <span style="display: inline-block; width: 15px; height: 15px; background-color: orange; border: 1px solid black; margin-right: 5px;"></span> Sand plains            |
| <span style="display: inline-block; width: 15px; height: 15px; background-color: pink; border: 1px solid black; margin-right: 5px;"></span> Stony plains with ironstone gravel  | <span style="display: inline-block; width: 15px; height: 15px; background-color: blue; border: 1px solid black; margin-right: 5px;"></span> Wooded downs             |

**Fig 1.2 Land zones of the study area (modified from Wilson and Purdie 1990)**

The first pastoral leases in the area were established along the major watercourses and tributaries of the Diamantina and Georgina river systems in the present study area, thirty years after Charles Sturt first visited in 1845.

The current properties “Glengyle”, “Adria Downs” (formerly “Annandale”), and “Roseberth” were taken up in 1876 and “Sandringham” in 1877. “Monkira”, “Mt. Leonard”, “Cluny” and “Coorabulka” were other early holdings (Wilson *et al.* 1990).

The climatic vagaries and lack of natural waters resulted in early settlers drifting away from the area by 1890 with frequent property amalgamations taking place as a result (Wilson *et al.* 1990). Current property sizes are smaller (500 -1000 km<sup>2</sup>) in the north and north east of the area where sheep grazing predominates, and considerably larger (4000 - 25000 km<sup>2</sup>) for the remainder of the area where cattle grazing occurs.

Land tenure is predominantly leasehold.

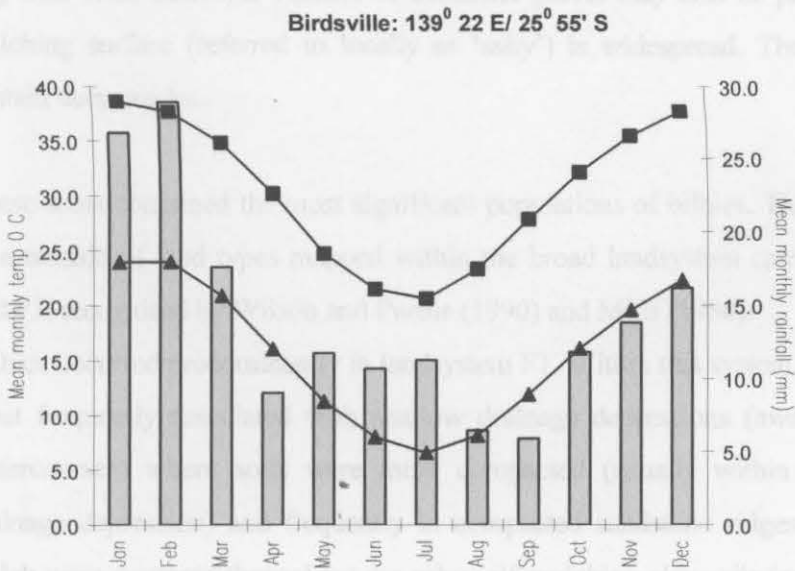
Two National Parks exist in the area: Diamantina NP (700 000 ha) was gazetted in 1991, and Astrebla Downs NP (170 000ha) in 1995. The latter was the major field site for the detailed studies on bilbies reported in the following chapters of this thesis.

## **1.3 BILBY HABITAT**

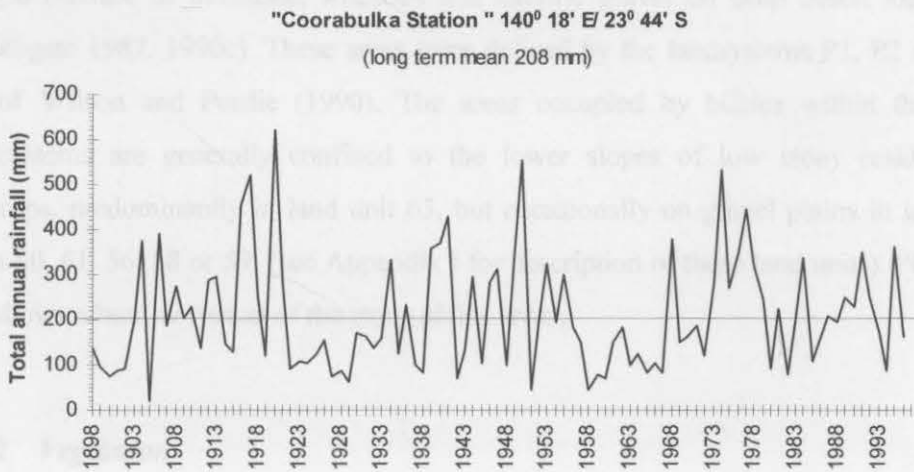
### ***1.3.1 Geology and landzones***

The geology of the study area reflects an eroded tertiary landscape, which has exposed fresh and deeply weathered sediments of the Winton, Mackunda and Wilgunyah formations (Wilson and Purdie 1990). Scattered extant populations of bilbies occur within land zones F (undulating cracking clay plains) and P (stony plains) (see Fig 1.2)

Two broad habitat types were recognised in Queensland and they concur with those identified by Southgate (1987, 1990a, 1990c).



**Fig 1.3 Mean monthly temperature and rainfall for Birdsville. (Data from 100 years of records Commonwealth Bureau of Meteorology).**



**Fig 1.4 Historical mean annual rainfall for Coorabulka Station. (Data from 99 years of records Commonwealth Bureau of Meteorology).**

These are described below:

i) **Clayey plains:** These extensive areas of deep to moderately deep red and brown calcareous clays are interspersed with shallower clays over sandstone ridges, which may also form outcrops. Patches of ironstone gravel may also be present. A self-mulching surface (referred to locally as 'ashy') is widespread. The surface may contain deep cracks.

These areas contained the most significant populations of bilbies. The areas consist of a mosaic of land types mapped within the broad landsystem categories: F1, F2 and F3, recognised by Wilson and Purdie (1990) and Mills (1980).

Bilbies occurred predominantly in landsystem F1. Within this system, burrows were most frequently associated with shallow drainage depressions (away from major watercourses) where soils were more compacted (usually within 100m of the drainage depression) and frequently in compacted sandstone ridges and outcrops which were scattered throughout the ashy self-mulching clay soils (see Appendix I, land unit 45 and 46).

Plates 1.3 and 1.4 show burrows in typical ashy plains areas.

ii) **Stony plains:** These are low hills that rise gently from the plains that are covered with a mixture of ironstone, siliceous and lateritic gravel on deep desert loams (Southgate 1987, 1990c). These areas were defined by the landsystems P1, P2 and P3 of Wilson and Purdie (1990). The areas occupied by bilbies within these landsystems are generally confined to the lower slopes of low stony residual outcrops, predominantly in land unit 63, but occasionally on gravel plains in land units 60, 61, 56, 58 or 59. (see Appendix I for description of these land units). Plate 1.6 shows a burrow typical of the stony plains areas.

### 1.3.2 *Vegetation*

i) **Clayey plains:** Vegetation is sparse and dominated by a variety of annual and perennial chenopods and grasses. Dominant chenopods include *Salsola kali*,





**Plate 1.3 *Macrotis lagotis* burrow in clay plains habitat**



**Plate 1.4 *Macrotis lagotis* burrow in clay plains habitat**



**Plate 1.5 Feeding scrapes of *Macrotis lagotis* in ashy plains habitat.**



**Plate 1.6 *Macrotis lagotis* burrow in stony plains habitat.**

*Sclerolaena calcarata*, *S. lanicuspis*, *Atriplex spongiosa*, *A. lindleyi*, *A. muelleri* and a number of *Maireana* species. Dominant grass species include *Astrebla pectinata*, *Dactyloctenium radulans*, *Erneapogon polyphyllus*, *Sporobolus actinocladius*, *Chloris pectinata*, *Iseilema vaginoflorum*, *Dicanthium sericeum* and *Triraphis mollis*. Trees are restricted to the middle and lower reaches of the major drainage lines and consist of *Eucalyptus coolibah* sometimes with *Acacia cambagei*. The open plains are largely free of trees apart from very isolated patches of *Atalaya hemiglauca* growing to 3-4 m. A low open shrub stratum of *Acacia victoriae* to 2-3 m is sometimes present along drainage lines and on sandstone ridges. Other low shrub species such as *Senna barclayana*, *Cynanchum floribundum* and *Enchylaena tomentosa* were sometimes present in low densities, particularly associated with drainage depressions and local depressions such as gilgais. Ground cover recorded in areas occupied by bilbies was generally less than 10 %.

ii) **Stony plains:** Vegetation structure is sparse to open, low chenopod herbland or grassland. Dominant chenopod species include *Sclerolaena* spp. and *Maireana* spp. Scattered clumps of low shrubs including *Acacia victoriae*, *Senna nemophila*, *S. artemisioides helmsi* and *S. a. phyllodinea* are also present at times. Small trees such as *Atalaya hemiglauca* were sometimes present, and sparse, low woodland of *Acacia peuce* occurs approximately 14 km north of Birdsville. *Eucalyptus coolibah* and/or *Acacia cambagei* low open woodland dominates the major drainage lines in the area. Ground cover recorded in areas occupied by bilbies was generally less than 10 % and often less than 5 %.

The species utilizes a wide diversity of landtypes throughout its range in Australia (see Southgate 1990a, 1990c). Historical records of its occurrence in Queensland indicate a former greater diversity of landtypes were inhabited; for example, dunefields around Birdsville and Bedourie; mulga lands biogeographic region around Quilpie, Cunnamulla and Hungerford; southern brigalow biogeographic region around Surat.

Four recently active burrows were found in dune fields at Diamantina National Park in October 1993 during the course of this study, however no evidence for the persistence of the species at this site exists.



## 1.4 STRUCTURE OF THIS THESIS

Chapter 2 deals with aspects of the biology and ecology of *Macrotis lagotis* in Queensland. Their spatial organisation and use of burrows is explored in Chapter 3, and the development and use of aerial survey techniques based on the distribution of burrows is described in Chapter 4. Chapter 5 then puts the current distribution of bilbies into an historical context, and explores the factors attributed to the range declines observed since the European settlement of Queensland. Chapter 6 deals with current threats to the extant populations in Queensland, and the implications of these to the future management and conservation of the species are discussed in Chapter 7.

## CHAPTER 2

### *ASPECTS OF THE BIOLOGY AND NATURAL HISTORY OF THE BILBY IN QUEENSLAND*

---

#### 2.0 INTRODUCTION

In this chapter I report on aspects of morphology, reproduction and natural history of bilbies obtained from a wild population. Body measurements made on live, wild-caught animals are not as precise (perhaps with the exception of measurements related to living tissue and body mass) as those from museum specimens. However, data from a wild population of bilbies are not currently available, and these data provide an important contribution to our knowledge of the species.

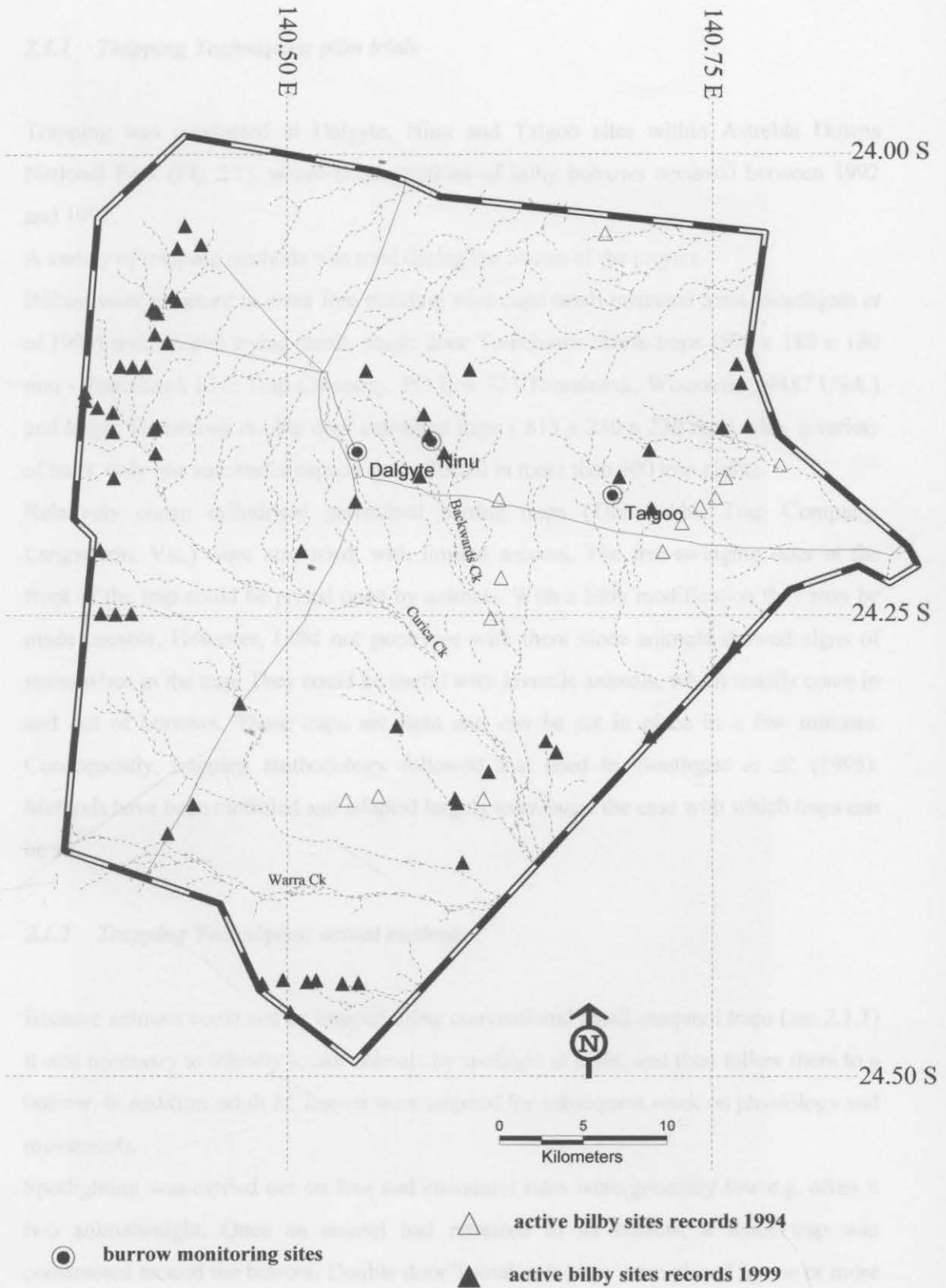
Because the aspects of bilby biology covered in this chapter are quite diverse, I have adopted the approach of presenting a series of sections on Results and Discussion, following a general Methods section that describes the various procedures used in the field.

The study site, Astrebla Downs National Park, is shown in Fig 2.1.

#### 2.1 CAPTURE, HANDLING AND GENERAL METHODS

Bilbies are well armed with polyprotodont dentition and are quite capable of inflicting a serious bite, but do so reluctantly and fortunately, for human handlers, infrequently. If by chance they do bite, it is not uncommon for them to take a single bite and hold on with a vice- like grip. Most animals, however, have a placid nature and can be handled easily in a calico bag with a minimum of restraint.

Males in particular are characterised by an unusual musty odour similar to but much 'sweeter' than that of *Mus domesticus*.



Note : Talgoo, Ninu and Dalgyte sites were used for radio telemetry analysis of home range and burrow use.

Fig 2.1 Astrebla Downs National Park showing location of study sites.

### **2.1.1 Trapping Techniques: pilot trials**

Trapping was conducted at Dalgyte, Ninu and Talgoo sites within Astrebla Downs National Park (Fig 2.1), where concentrations of bilby burrows occurred between 1992 and 1997.

A variety of trapping methods was tried during the course of the project.

Bilbies were reluctant to enter free standing wire cage small mammal traps (Southgate *et al.* 1995) and, despite trying small, single door Tomahawk skunk traps (500 x 180 x 180 mm - Tomahawk Live Trap Company, PO Box 323 Tomahawk, Wisconsin 54487 USA.) and larger Tomahawk double door cat/rabbit traps ( 813 x 230 x 230 mm) with a variety of baits, only one successful capture was effected in more than 600 trap nights.

Relatively cheap cylindrical galvanised netting traps (The Rabbit Trap Company, Langwarrin, Vic.) were also tried, with limited success. The free-swinging door at the front of the trap could be prised open by animals. With a little modification they may be made useable. However, I did not persevere with them since animals showed signs of stress when in the trap. They could be useful with juvenile animals, which readily come in and out of burrows. These traps are light and can be set in place in a few minutes. Consequently, trapping methodology followed that used by Southgate *et al.* (1995). Methods have been modified and adapted largely to enhance the ease with which traps can be set.

### **2.1.2 Trapping Techniques: actual methods**

Because animals could not be trapped using conventional small mammal traps (see 2.1.1) it was necessary to initially locate animals by spotlight at night, and then follow them to a burrow. In addition, adult *M. lagotis* were targeted for subsequent work on physiology and movements.

Spotlighting was carried out on foot and encounter rates were generally low e.g. often < two animals/night. Once an animal had retreated to its burrow, a fence trap was constructed around the burrow. Double door Tomahawk traps were placed in one or more of the fence panels and covered with canvas. Traps were baited with bird seed based on millet. Traps are shown in Plates 2.1 and 2.2.



**Plate 2.1** A single entrance burrow trap set for *Macrotis lagotis*



**Plate 2.2** A multiple entrance burrow trap set for *Macrotis lagotis*

The modular panels (900 mm x 2000 mm) were framed by 6 mm steel rod, and 10 mm x 10 mm galvanised bird netting was supported within this frame. Panels were individually locked together by a length of 6 mm steel rod, which extended approximately 300 mm into the ground and provided support for the whole structure. Each panel had 200 mm of the steel rod frame extending down from each end into the ground to provide additional support. A length of galvanised bird netting was attached along the bottom edge of each panel and was folded out and covered with soil when the trap was set to prevent animals digging out. The trap panels were transported on brackets attached to the side of a vehicle that was located away from the search area and driven to the trap site once an animal was located. The method required a minimum of two people to work effectively. With three people, (two spotlighting and one waiting in the vehicle), a much greater coverage could be achieved.

The time needed to set a basic four-panel trap varied between 20 and 40 min, and was quite labour intensive. Given the low densities of animals and variation in the complexity of burrows, frequently only two or three traps could be set in 5-6 h of spotlight searching, although on occasions up to five were set. Generally trapping was carried out on three consecutive nights at a particular site and then spelled for one or two nights. Trapping was also best performed a week either side of a new moon, but this was not always possible.

Traps were checked the following morning and any animals caught were placed in calico bags and transported to camp for processing.

Body measurements taken were: body mass, head width, head length, ear length, pes length, tail length, tail basal diameter, canine width, testis width and length. Pouches of females were inspected for young. In addition, an assessment of the condition of each animal was made based on the criteria in Table 2.1, which was developed with the assistance of veterinary advice from K. Cornack. Observations of colour variation and ectoparasites were recorded. Body temperature was recorded with a digital rectal thermometer.

Any faecal pellets deposited in the trap were collected and subsequently weighed and measured. These data were collected to assist with developing growth indices of growth

and age, as well as providing descriptive mensurative data from a wild population. These data are not reported within the scope of this thesis.

**Table 2.1 Criteria used to assess condition of *M. lagotis*.**

Condition	Condition Score	Assessment Criterion
<b>Emaciated</b>	1	Lumbar vertebral spinous processes > 2mm above lumbar muscle mass; ribs visible
<b>Poor</b>	2	Lumbar vertebral spinous processes prominent; 2mm above lumbar muscle mass
<b>Thin</b>	3	Lumbar vertebral spinous processes easily distinguishable; 1mm above lumbar muscle mass
<b>Good</b>	4	Lumbar vertebral spinous processes confluent with lumbar muscle mass; just distinguishable under light finger pressure
<b>Fat</b>	5	Lumbar vertebral spinous processes well covered; distinguishable only under heavy finger pressure
<b>Obese</b>	6	Lumbar vertebral spinous processes covered in fat and not palpable

Fresh pellets were collected from various sites on all field trips since 1989 and are available for dietary analysis. Pellet dimensions were measured with digital vernier callipers. Diameter was measured at the broadest point at the posterior end. Pellets were recorded as 'fresh' if they had an aromatic quality when broken in two. Old pellets were characterised by a chalky white exterior and lack of aroma. In addition, old pellets tended to occur scattered singly on the surface, probably as a result of past disturbance and scattering from wind, rain or other species.

All animals were marked with ear punched numerical tattoos to enable recapture identification of individuals.

Trap doors were closed to exclude entry of other species until the animal was returned to its burrow later in the day. If an animal was not caught on the first night, the trap was closed and re-set later the same day. This procedure was repeated for up to three nights, after which the trap was pulled up.

All body measurements were taken without the use of anaesthesia, using digital vernier callipers. Body mass was recorded using Pesola and Salter spring balances.

## 2.2 TRAPPING RESULTS

Trapping methods used were the best available, however, losses were recorded.

Of 226 trap records between 1989 and 1997, eight deaths were recorded: three animals were found dead in traps, with signs of stress, attributed to harassment by dingoes whilst in the cage trap. During the radio tracking studies reported in Chapter 3; two radio collars were found with cat chew marks; one sick collared animal was hand caught and subsequently died of tetanus; two collars were found with no evidence or clues as to what had transpired i.e. the collar could have fallen off, or the animal died and birds picked up the collars.

### ***2.2.1 Trap Success***

Figures 2.2 and 2.3 show results from all trapping during 1992 and 1995-1997.

Trap success improved over the study period (28% in 1992, 72% for 1995-1997). The improvement in the success rate of trapping shown in Fig 2.2 is attributed to a combination of improved technique and design, whilst the decline in success rate on subsequent nights (Fig 2.3) results from an inability to determine if an animal had escaped or was simply trap shy. Also, an increase in first night success would result in diminished success on nights two and three. In most cases evidence of an escape was obvious; however, uncertainty of an animal's whereabouts existed, if it wasn't present in the cage trap.

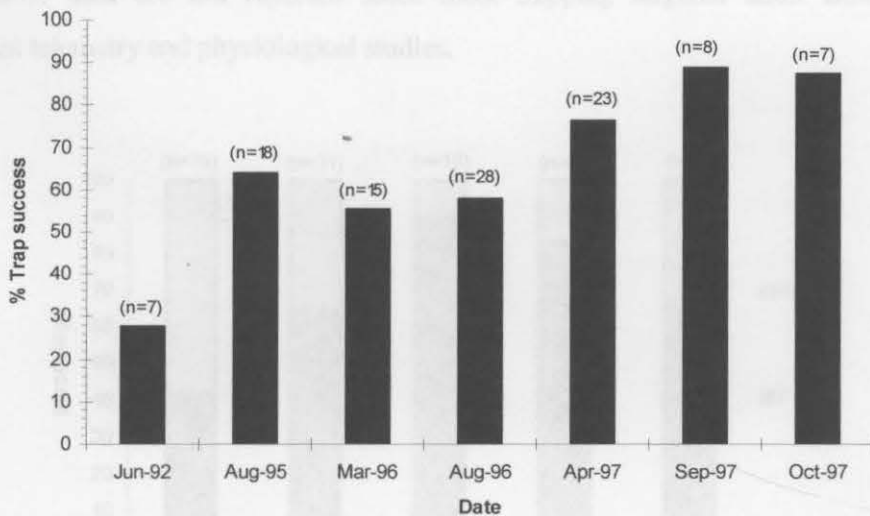
### ***2.2.2 Sex ratio of captures***

Overall capture data reveal a sex ratio of 54 % female and 46% male (n = 126). Although these data are not far removed from parity, they do reflect encounter rates which, given the larger areas used by males (see Chapter 3) is likely to reduce encounter rates with them.

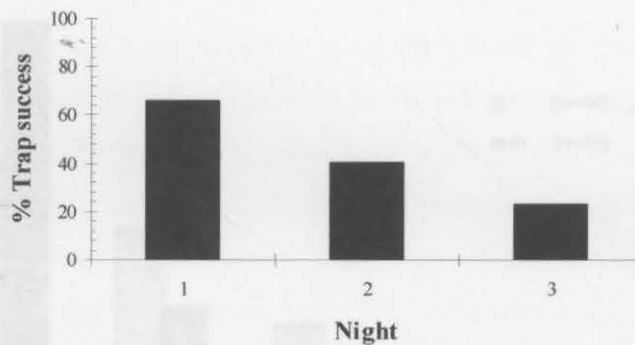
### ***2.2.3 Recapture rates***

Recapture data are shown in Figs 2.4, 2.5 and Table 2.2. Subsequent recapture of animals was heavily biased towards females (Fig 2.4); for example, 90% of animals recaptured twice were females. The convergence in the tails of the male and female data in Fig 2.4





**Fig 2.2 First night trap success for *Macrotis lagotis* at Astrebla Downs National Park 1992 and 1995 – 1997 (n=70).**



**Fig 2.3 Overall trap success for *M. lagotis* on consecutive nights (n = 106).**

could result from a real biological factor such as age-specific survivorship, but is more likely attributed to small sample sizes. The fact that 60% of all animals trapped (n=126) were never recaptured suggests either high mortality or loss of animals to the population through dispersal. The fact that 42% of these were females (Fig 2.5) this might suggest dispersal rather than sex-biased mortality i.e. males are more mobile and thus less likely to be recaptured. These data however should be viewed with caution given the inherent problems with trappability of the species.

Age specific data are not reported since most trapping targeted adult animals for subsequent telemetry and physiological studies.

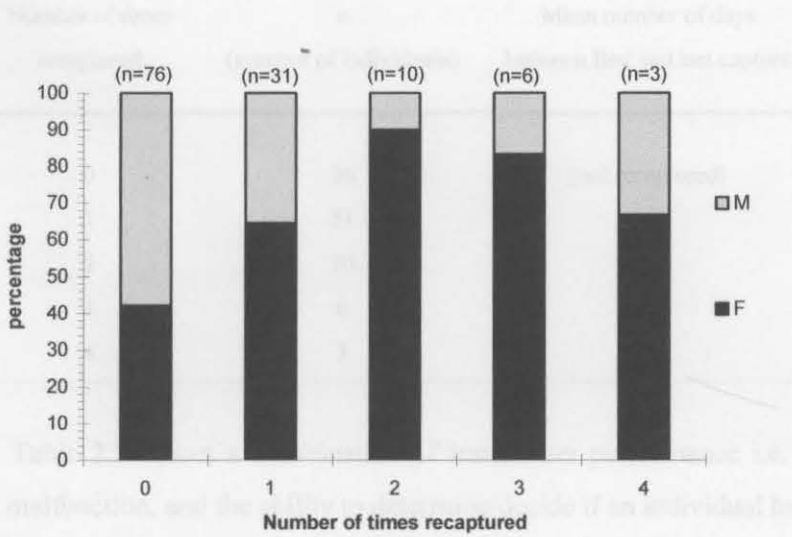


Fig. 2.4 Sex ratio of recaptured *Macrotis lagotis*. ( n = 126 ).

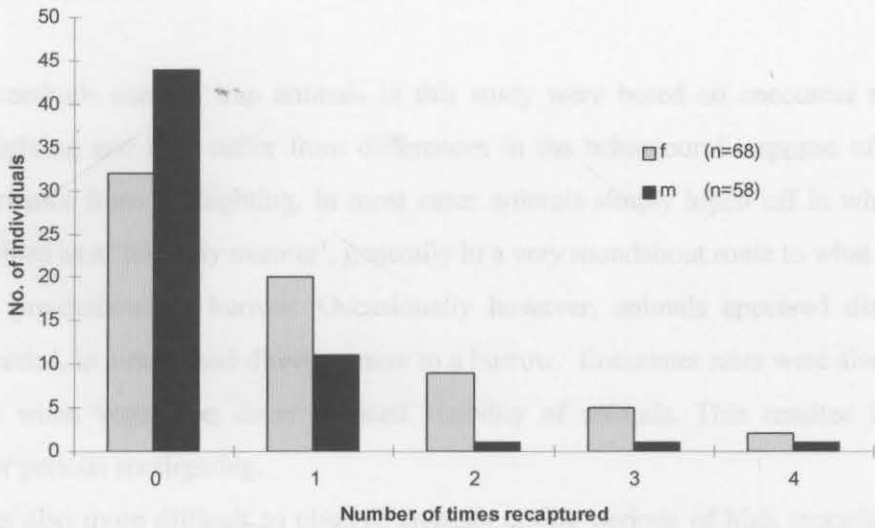


Fig. 2.5 Recapture data for all *Macrotis lagotis* recaptured greater than 30 days from first capture.

**Table 2.2 Mean number of days between successive captures.**

Number of times recaptured	n (number of individuals)	Mean number of days between first and last capture
0	76	(not recaptured)
1	31	164
2	10	292
3	6	379
4	3	617

The data in Table 2.2 reflect a combination of transmitter performance i.e. battery life longevity or malfunction, and the ability to determine/decide if an individual had dispersed out of the area, had died of natural causes or been taken by a predator.

#### **2.2.4 Discussion**

The methods used to trap animals in this study were based on encounter rates during spotlighting and thus suffer from differences in the behavioural response of animals to disturbance from spotlighting. In most cases animals simply loped off in what could be described as a 'leisurely manner', generally in a very roundabout route to what appeared to be a pre-determined burrow. Occasionally however, animals appeared disturbed and proceeded, in a rapid and direct manner to a burrow. Encounter rates were also reduced at times when vegetation cover reduced visibility of animals. This resulted in spending longer periods spotlighting.

It was also more difficult to observe animals during periods of high moonlight. During these times animals were more cautious, however this didn't affect trap success rates, but reduced encounter rates.

Any future study requiring continued trapping of wild bilbies would benefit from using improved trapping methodologies. Improvements could include a new lightweight fence trap, which would improve the set up time, or a completely new design of trap allowing overall improvements in ease of setting and time. Further investigation of a trapping

methodology that could enable systematic sampling of populations would greatly enhance the ability to investigate some of the population processes mentioned above e.g. mortality and dispersal. Studies could involve utilisation of different combinations of traps and baits/lures that might enable trapping of animals above ground during routine foraging movements and thus enable the establishment of trapping grids and a better analysis of population processes.

### **2.3 BREEDING AND POUCH YOUNG**

Females have a pouch that opens to the rear and contains eight nipples.

Of 88 females trapped, 51% had two pouch young, 28% had one, and 14% were barren. Three pouch young were recorded on three occasions and four in one instance. Of the 14 females with no pouch young, eight were lactating and three were nulliparous.

Breeding was recorded throughout the year.

### **2.4 MORPHOMETRICS**

#### ***2.4.1 Results and Discussion***

##### ***2.4.1.1 Size***

The species is sexually dimorphic for size, though it would appear that dimorphism is not as marked in Queensland as in other parts of the species' range.

Mean adult mass obtained for wild males was  $1095 \pm 39$  g (mean  $\pm$  s.e., max.1730 g, n=64), and for females  $824 \pm 18$  g. (mean  $\pm$  s.e.; max.1190 g, n=68). These results are based on all animals above 500 g in mass trapped during the study. This cut off point was chosen because females generally didn't produce their first pouch young prior to attaining this mass and hence were not classified as adults. The female data may be biased towards the heavy end since most females of reproductive age that were trapped had pouch young or were lactating. However, in all cases, pouch young still had their eyes closed and were thus not likely to contribute much more than 80-100 g to the overall mass of the female. Two of 14 females over 1000 g in mass were without pouch young and weighed in excess of 1100 g.

Queensland animals are smaller than those from Western Australia and the Northern Territory. Johnson (1983, 1989) reported a similar female mass range to that reported here, but males attained a maximum mass of 2.5 kg. His data were based primarily on captive animals (R. Southgate pers. comm.) and concur with masses obtained for captive animals at Charleville (P. McRae unpublished).

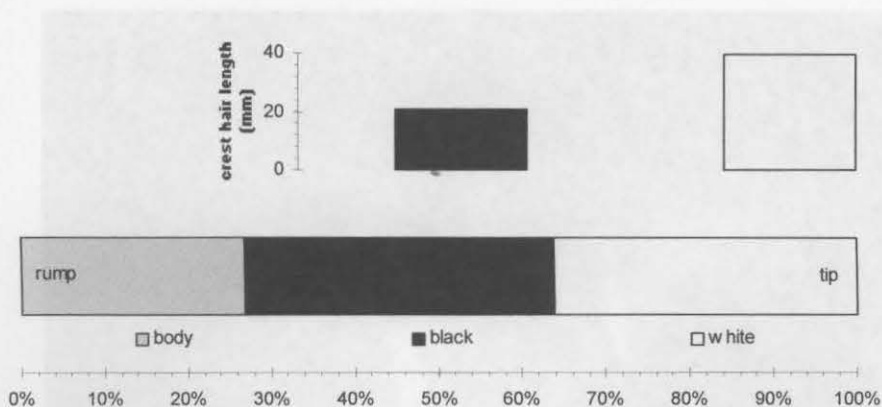
#### 2.4.1.2 Colour

The body fur is thick and silky, fine in texture and a light ashy blue grey in colour with distinct and variable areas of white and light tan on the hips and shoulder. A hip stripe of light tan to white extends from the thigh to base of tail. White from the ventral surface extends upwards laterally forward of the hip stripe and may be bordered with tan also. An area of darker grey to black extends from the front of the shoulder down for approximately two thirds the length of the radial section of forelimb. The remainder of the limb is white, as is the manus. A similarly coloured area extends from the tail base along the back of the thigh to the heel of the hind limb. The upper surface of the pes is white whilst the ventral surface is clothed with varying amounts of black or white hair with the exception of the heel and large tarsal pads. The mean extent of the black area was 47.5 % of the length of the pes (range 17% -100 %, n= 29).

The variability in the extent of the black areas on the soles of the pes was formerly the basis for the description of the subspecies, *Macrotis lagotis nigripes*. No subspecies are now recognised following the revision by Troughton (1932).

The ventral surface is creamy white.

The strikingly tri-coloured tail is ashy blue grey with body fur at the base (27% of the tail length), black in mid section (37%) and white terminally (36%) (Fig 2.6). These proportions are similar to those reported by Johnson (1989), 20%, 40% and 40%, in his review of the Thylacomyidae. The tail possesses an unusual dorsal crest of coarse hairs throughout its length. These hairs are progressively longer towards the tail's extremity (Fig 2.6). The tail terminates in a soft, naked tip that appears to progressively cornify with age to produce a horny spur (see Section 2.8) up to 7 mm in length. The longer white caudal hairs at the extremity of the tail tend to hang down and partly cover this horny spur.



**Fig 2.6 Percentage composition of colour on the tail, and length of caudal crest hair of *Macrotis lagotis* (data obtained from 29 wild caught animals at Astrebla Downs NP 1996 - 1997).**

#### 2.4.1.3 Head

The upper surface of the snout is generally naked from the tip, extending approximately half of the distance to the eyes, and is often calloused. The ears are large, and for the most part naked, and ranged in length between 54% and 90% the length of the head ( $n = 47$ ) for adult males and between 73% and 90% for adult females ( $n = 63$ ).

Much has been touted in the popular literature as to the function of such large ears and has mainly centered around the large surface area contributing to evaporative heat loss (see Schmidt-Nielsen 1964, Johnson and Johnson 1983). I cannot contribute any additional information to unravel ear morphology other than to suggest that the function might be primarily related to hearing! As a result of field observations I suggest that an entirely functional aspect of ear size could relate to the fact that when feeding, the animal's long snout is often deeply embedded in a conical feed scrape which may be 20 to 30 cm in depth. Long ears would thus enable some sensory contact with the above-ground surroundings whilst the eyes and nose were below ground. Perhaps a further function of large ears and probably unrelated to hearing is shown in Plate 2.3.



**Plate 2.3** Sleeping juvenile *Macrotis lagotis* with the greater part of its head nestled in an adult female's ear.

Adult animals exhibit sexual dimorphism in head length and head width (see Table 2.3). Males had significantly longer and wider heads (head length, t-test;  $t_{37} = 9.948$ ,  $p < 0.001$ ; head width, t-test;  $t_{37} = 9.241$ ,  $p < 0.001$ ). Adult males as a result have a much broader and bulkier head giving the appearance of a shorter snout.

**Table 2.3** Head measurements of adult *M. lagotis* (mean  $\pm$  s.e.).

	Head length (mm)	Head width (mm)
Male (n=38)	105.0 $\pm$ 1.3	43.8 $\pm$ 0.8
Female (n=58)	94.5 $\pm$ 0.7	37.4 $\pm$ 0.3

#### 2.4.1.4 Dentition

In common with other peramelids, *Macrotis lagotis* is polyprotodont with a dental formula of: **I** 5/3, **C** 1/1, **PM** 3/3, **M** 4/4 (Wood Jones 1924).

Figs 2.7 and 2.8 show the lower jaw of a juvenile male and adult male, respectively, from the study site. In Fig 2.7 molars 1-3 are fully erupted, M4 and PM3 are partially erupted and no teeth show signs of any cusp wear. The cusps of the mandibular molars are progressively worn with age to an extent that eventually the tooth surface is obliquely flattened outwards at an angle and becomes confluent with the outer margin of the mandible (Fig 2.8). Occlusion results in a reversal of the wear pattern on the surface of the maxillary molars and tooth wear becomes flattened lingually (inwards) in a line from the tooth crown to the palate. The premolars, which are compressed with a single row of tubercles, also show signs of wear with age, however, this wear is more evenly distributed across the whole of the dorsal surface of the tooth and results in the cusps becoming more rounded and flattened (Figs 2.7 and 2.8). This is probably due to the narrower profile and surface area of the premolar cusps and the extent of occlusal contact with the lower jaw during mastication.

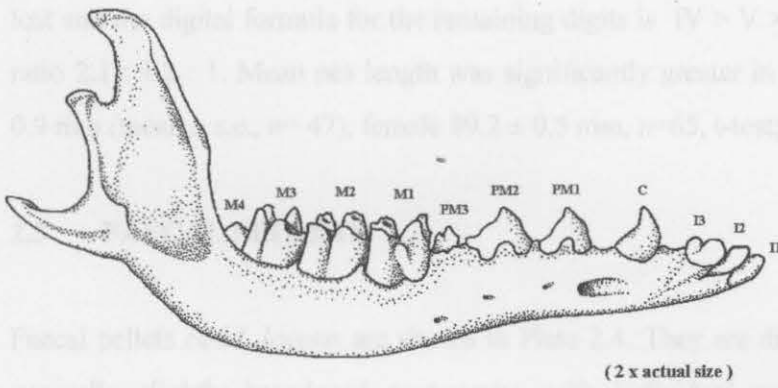
Upper canines are large and in males can be up to 10 -12 mm in length. In this study, basal canine width (measured along the axis of the upper jaw) of adults was greater in males,  $3.04 \pm 0.13$  mm (mean  $\pm$  s.e.,  $n=43$ ) than females,  $2.21 \pm 0.04$  mm ( $n=49$ ) (t-test;  $t_{89} = 6.447$ ,  $p < 0.001$ ).

Johnson and Johnson (1983) thought that the dimorphism between sexes in canine size had a basis in threat displays.

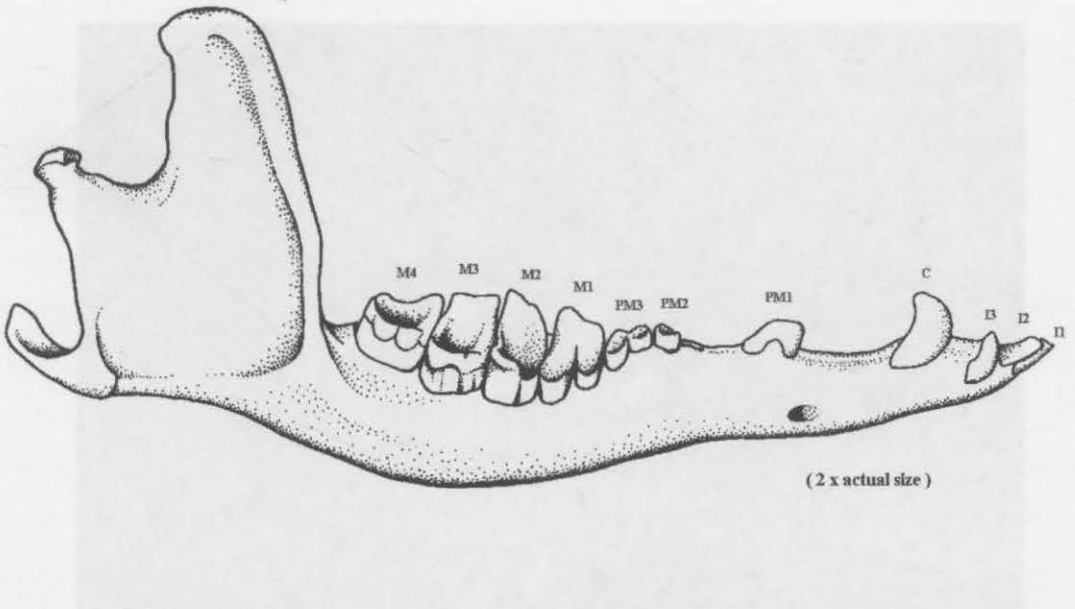
#### 2.4.1.5 Limbs

Forelimb skeletal support is associated with a well developed shoulder muscle mass. The limbs terminate with digits II, III and IV, each of which are approximately equal in length and possess a long, sharp digging claw. Digit V is reduced in size and is clawless. Hindlimbs are macropodid-like, with syndactyl grooming claws. The first digit has been





**Fig 2.7** Right dentary of juvenile male *M. lagotis* showing no molar wear and partial eruption of M4 and PM3. (drawing by Kyra Kopestonsky from material provided by P. McRae)



**Fig 2.8** Right dentary of adult male *M. lagotis* showing molar and premolar wear and full eruption of M1 to M4. (drawing by Kyra Kopestonsky from material provided by P. McRae)

lost and the digital formula for the remaining digits is IV > V > II, III in the approximate ratio 2.1 : 1.2 : 1. Mean pes length was significantly greater in adult males (male  $95.6 \pm 0.9$  mm (mean  $\pm$  s.e.,  $n=47$ ), female  $89.2 \pm 0.5$  mm,  $n=65$ , t-test;  $t_{46} = 10.079$ ,  $p < 0.001$ ).

## 2.5 FAECAL PELLETS

Faecal pellets of *M. lagotis* are shown in Plate 2.4. They are distinctively cylindrical but generally slightly broadened posteriorly, with individual pellets possessing a short constriction point; the anterior face is obliquely flattened. However, the most characteristic features of pellets are the high content of soil and their low moisture content.

Pellets are generally deposited individually in groups of from three to 15, but occasionally are voided strung together. They are most frequently voided when animals are digging for food, which results in the pellet group being covered by excavated soil.

Groups of pellets from individual animals varied markedly in length but showed little variation in diameter. Results are shown in Table 2.4.



Plate 2.4. Faecal pellets of *Macrotis lagotis*.

**Table 2.4 Faecal pellet dimensions for *Macrotis lagotis*.**

Adult data based on 280 pellets (11 female, 8 male); Juvenile data from 61 pellets (2 male, 2 female).

	length (mm) ± s.e.	diameter (mm) ± s.e.
adult	17.1 ± 0.3	9.5 ± 0.1
juvenile	13.7 ± 0.4	7.0 ± 0.1

It is possible that once sufficient long-term data have been collected on known-age animals, pellet diameter may be used to develop an indirect index of age structure of wild populations. This would benefit future monitoring of the age structure of wild populations without the need to trap and disturb animals.

## 2.6 DIET

Detailed research on the diet of the species in Queensland has been reported by Gibson (1999, 2001), in studies carried out concurrently with this project during 1995-1998.

Estimates of the diet determined from faecal pellet analysis have also been reported by Southgate (1990 a, c).

Gibson (2001) reported that the species is a generalist omnivore that is primarily insectivorous in summer and granivorous in winter. Termites and the seeds of button grass (*Dactyloctenium radulans*) were the most important dietary items. Gibson (2001) suggested that this broad dietary strategy of *M. lagotis* allows it to live in the arid zone where food resources are spatially and temporally variable.

Observations on food selection by bilbies were conducted over the duration of this project and some observations are reported below:

- Particularly obvious was the frequent observation of feeding excavations (feed scrapes) that were made into the nests of subterranean termites and those of small (2-4 mm) seed harvesting ants, *Melophorus sp.* Both were characteristic and observed throughout the year;

- The ant nests were generally obvious in that ants were frequently observed furiously attempting to repair the damage done to their nest. In one instance a trail of hundreds of ants carrying seed and larvae from a bilby-damaged nest was followed for approximately 30 m to a new nest;
- The subterranean termite mounds were characterised by excavated chambers that were filled with small (5-10 mm), neatly cut lengths of dry plant stems. Also evident were chambers filled with a mass of hardened grey/brown material of indeterminate origin. This could be decayed plant material, stored waste excreta or of some other origin. This material was frequently found mixed with soil in faecal pellets. These termite chambers were invisible above the ground, and their presence would never have been expected, except for their excavation by bilbies;
- Grasshopper femurs were frequently observed in the pellets when abundant, particularly those of wingless species;
- Elytra of beetles and exoskeletons of termite head capsules were also evident in pellets;
- Scales of the bulbs of bush onion (*Cyperus bulbosus*) were very evident in pellets when bush onion formed the basis of their food. This species belied its presence by not being visible above the ground most of the time. The vegetative parts of the plant have only been recorded on a few occasions in 15 years of visits to the area. Consumption of bush onion produced pellets of a darker colour;
- Button grass seeds were also very evident in pellets due to their distinct red/orange colouration. These may have been accidentally ingested from the nests of seed harvesting ants;
- Mammal hair was recorded in faecal pellets on one occasion;
- Bilbies appear to use smell to locate their food particularly that which occurs on, or under the ground. Animals were observed at night to move with their nose continually 'smelling' the ground, in a fashion similar to 'sniffer' dogs.

Johnson and Johnson (1983) alluded to a peculiar pea-shaped body in the corner of the mouth, which from the one female they examined, appeared to have no glandular structure.

They suggested this structure might have a basis in threat displays.

The structure was also observed in both sexes during the present study. More detailed histological examination may reveal a glandular association with the temporary cheek pouches, which have been observed to form when animals engorge themselves with seed. (Plate 2.5).

## 2.7 ECTOPARASITES

Fleas and mites were present on most wild caught animals. Taxon details are provided in Table 2.5. Ticks were infrequently recorded, but fleas and mites were present on virtually all animals, with mites being the more abundant. Animals that were in poor condition or in a reduced state of health generally supported greater populations of both fleas and mites. Fleas tended to attach to the scrotum of males in poor health. The captive population of bilbies at Charleville have to date carried no ectoparasites.



**Plate 2.5 Temporary cheek pouches of *Macrotis lagotis*, filled with seed.**

This is interesting since ectoparasites were present on founding animals from the wild and none appear to have survived captive conditions at Charleville.

**Table 2.5 Ectoparasites recorded on *Macrotis lagotis* during this study.**

Taxon	Note	Identification Source
<i>Echidnophaga</i> spp. (flea)	Two species, <i>E. perilis</i> and <i>E. gallinacea</i> , have been previously recorded from <i>Macrotis</i> .	K. Lambkin, Qld Museum
<i>Mesolaelaps lagotissimus</i> (mite)		B. Halliday, CSIRO
<i>Ornithodoros gurneyi</i> (tick)	First record for the species on <i>Macrotis</i> , normally found on macropod hosts.	D. Kemp, CSIRO

**2.8 GAIT AND TRACKS**

Animals display an unusual half-hopping gait, which results from the hind feet being moved forward together. Forelimbs are moved forward alternately usually with one in front of the other - see Plate 2.6. When disturbed, bilbies are capable of bursts of speed with frequent rapid directional changes. During these rapid escape movements the tail is held erect and the black and white portions present a distractive flashing which results in a perception of the tail going one way and the animal the other. This behaviour is probably important in predator avoidance.

During normal (i.e. undisturbed) locomotion, bilbies move about with the tail arched downwards, when it is moved both vertically and laterally, with the naked cornified tip the only point of contact with the soil surface. I suggest the cornifying of this initially soft naked tip is a result of this locomotory behaviour.





**Plate 2.6** Tracks of *Macrotis lagotis* in soft wheel tracks.

## 2.9 BODY TEMPERATURE

Body temperature of 32 wild animals (18 male, 14 female) was measured using a digital rectal thermometer. Mean body temperature obtained was  $35.6 \pm 0.2$  °C (mean  $\pm$  se).

Table 2.6 shows that these results are similar to those obtained from previous studies. Any differences probably reflect differences in technique in 'field' versus 'laboratory' conditions, or variation between instruments and recorders. In the laboratory studies thermocouples were used and were inserted deeper into the rectum and controlled ambient temperature conditions of 25 °C were maintained. In this study data were obtained as single readings in the field from 32 different animals using a small digital thermometer inserted approximately 1 cm into the rectum.

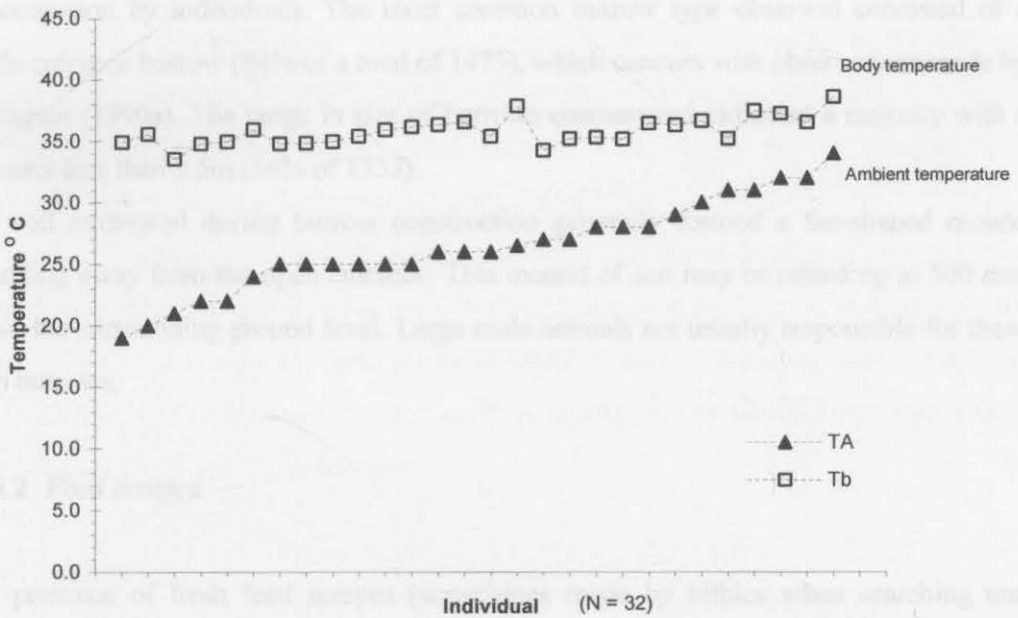
Body temperature records obtained over a range of ambient temperatures are shown in Fig 2.9. Body temperature was maintained over an ambient temperature range of 19-33°C.

**Table 2.6 Measures of rectal body temperature (mean  $\pm$  s.e.).**

Rectal Body Temperature ( $^{\circ}$ C)	$N_a^*$	$N_m^*$	Source
$34.9 \pm 0.1$	5	**	Hulbert and Dawson (1974a)
$35.2 \pm 0.2$	3	72	Kinnear and Shields (1975)
$35.6 \pm 0.2$	32	32	This study

•  $N_a$  = number of animals used;  $N_m$  = total number of measurements taken.

\*\* temperature was recorded continuously over a period of 24 h.



**Fig 2.9 Rectal temperature of *M. lagotis* at a range of ambient temperatures.**



## **2.10 BURROWS**

### ***2.10.1 Burrow characteristics*** -

The physical characteristics of bilby burrows have been reported in varying detail by Wood Jones (1924), Finlayson (1935b), Smyth and Philpott (1968), Watts (1969), Johnson (1989) and Southgate (1990a). All report that burrows are deep, generally spiralling or partially spiralling at an acute angle downwards, with few off-shoots to a depth of up to 2 m. No burrows were excavated during the course of this study. Burrows may be small with a single open entrance, or 'warren-like' complexes with a number of open entrances that reflected multiple occupancy by bilbies and other species.

Burrows in this study varied in size and form. Some consisted of a simple single entrance burrow with a total diameter (including the mound of excavated soil) of the less than 0.5m, to warren-like complexes up to 10 or 12 metres in diameter with a number of entrances and pop holes. These complexes probably reflect many years of occupation and re-occupation by individuals. The most common burrow type observed consisted of a single entrance burrow (84% of a total of 1475), which concurs with observations made by Southgate (1990a). The range in size of burrows encountered indicated a majority with a diameter less than 2.5m (56% of 1353).

The soil excavated during burrow construction generally formed a fan-shaped mound extending away from the open entrance. This mound of soil may be raised up to 500 mm above the surrounding ground level. Large male animals are usually responsible for these deep burrows.

### ***2.10.2 Feed scrapes***

The presence of fresh feed scrapes (scratchings made by bilbies when searching and digging for food) in an area is generally very indicative of bilby habitation. Previous studies by Smyth and Philpott (1968) and Southgate (1990a) indicated that foraging activity as evidenced by the presence of feeds scrapes occurred generally within 200 m of active burrows.

The present study revealed that of 1672 active burrows scored during survey work, 97% had feed scrapes present within a radius of approximately 5 m of the burrow. Feed scrapes clearly provide a good indicator of bilby presence in an area (see Plate 1.5 Chapter 1).

### **2.10.3 Burrow temperature**

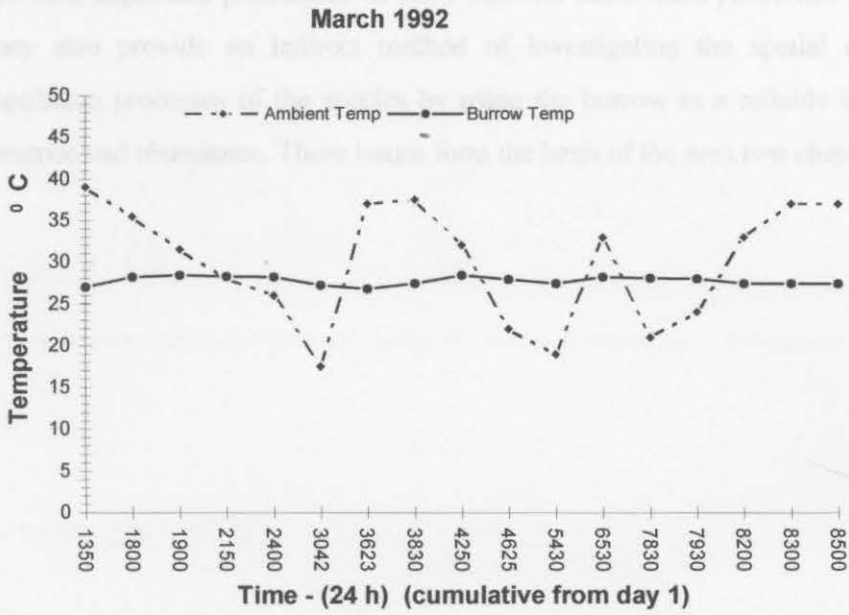
In addition to the significance of the burrow for protection against predators, the depth of the burrow produces a very stable thermal environment. The use of burrows in the arid zone provides a thermal retreat at times when temperatures reach extremes. Temperatures at the study sites frequently reached in excess of 50 °C in summer and fell to 0 °C in winter. Burrows also confer protection from a wide variety of predators.

The following data (Figs 2.10 and 2.11) from late summer and winter of 1992 provide evidence of this. These data were collected from an active burrow, but without an animal present. A temperature probe could only effectively be inserted a little over 1m into the burrow as a result of its spiral nature. Consequently the data may not reflect thermal conditions at the extremity of the burrow, or conditions apparent when an animal is present. The data however indicate a remarkably stable burrow environment. Mean burrow temperature in late summer was within the thermoneutral zone identified by Kinnear and Shields (1975) for the species (27 - 35 °C). That the winter burrow temperature is below the thermoneutral zone suggests that energy would have to be expended on thermoregulation during this time (see Gibson *et al.* 2002).

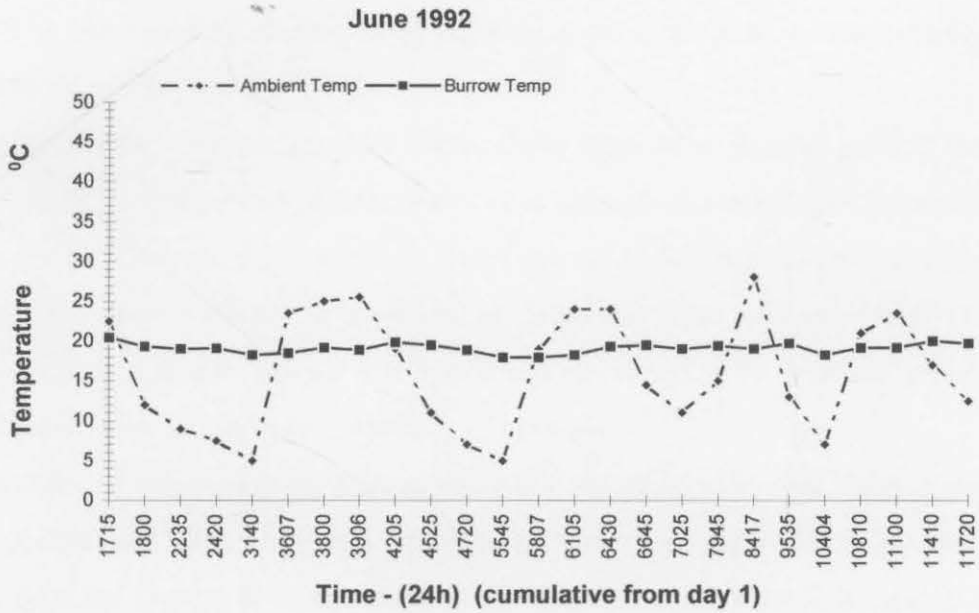
The greater depth (burrows to 2 m), narrowing of the chamber at depth, and presence of an animal, may decrease the temperature differential between the burrow and animal, and assist in reducing energy expenditure. Behavioural activities including back-filling may also enhance the temperature and humidity conditions in the burrow and reduce thermoregulatory demands in winter.

## **2.11 SUMMARY**

The aspects of biology and ecology of a wild population of bilbies reported above provide valuable background for the chapters to follow.



**Fig 2.10 Burrow and ambient temperature (late summer)**



**Fig 2.11 Burrow and ambient temperature (winter)**

The size, depth and persistence of bilby burrows make them prominent in the landscape. They also provide an indirect method of investigating the spatial organisation and population processes of the species by using the burrow as a reliable indicator of bilby presence and abundance. These issues form the basis of the next two chapters.

# CHAPTER 3

## *SPATIAL ORGANISATION AND USE OF BURROWS*

---

### 3.0 INTRODUCTION

This chapter reports on the use of burrows and patterns of movement by individual bilbies at three study sites, including preliminary data on nightly ranging of animals at one of the sites.

Burrow use by bilbies was investigated to establish numbers of burrows used by individual animals so that a method of monitoring population status could be developed using burrow counts as an index.

In Queensland the areas occupied by bilbies differ from those in other parts of the continent (1.3, Chapter 1). Queensland populations exist in open plains country and burrows are readily visible in the landscape, from both the ground and air. In Western Australia and the Northern Territory the species occurs in a variety of landscape types and vegetation communities including mulga, *Acacia aneura* and spinifex, *Triodia* spp. The structure and floristics of these communities greatly reduce visibility of burrows.

Studies utilising radio telemetry techniques were conducted at the sites Dalgyte (June-August 1992), Talgoo and Ninu (August 1995, March 1996, June-August 1996, March-May 1997) within Astrebla Downs National Park. The location of these sites is shown in Chapter 2, Figure 2.1.

### 3.1 METHODS

### ***3.1.1 Burrow surveys and site locations***

Potential sites were initially located using a reconnaissance helicopter survey. This was followed by extensive ground surveys, to areas located from the air, throughout the park. Sites that contained substantial aggregations of active burrows were then selected for future studies. All active burrows at sites were marked with small numbered wooden or metal stakes. Dalgyte site, with an area of 1km<sup>2</sup>, encompassed the majority of burrows (approximately 300 in total) in the local area. The other two sites were delineated by the areal extent of the burrow aggregation. Ninu site extended 100 m either side of 4 km of Ninu creek and contained approximately 80 burrows. Talgoo site, the largest in area (approximately 10 km<sup>2</sup>), contained the major drainage system of Talgoo Creek and a series of minor drainage depressions, and contained approximately 350 burrows (see Plates 3.1, 3.2, 3.3 and 3.4).

The geographical location of individual burrows was recorded using a Topcon Total Station (an electronic theodolite with an on-board database) to an accuracy of  $\pm 10$  cm. These data were then downloaded to a Geographical Information System (GIS), (MapInfo Professional, MapInfo Corporation) for mapping and spatial analyses.

### ***3.1.2 Trapping***

Animals were located and trapped using the methods outlined in Chapter 2, 2.2. Animals were released in the afternoon on the day of capture.

The impact of trapping on the subsequent movement of animals, and hence burrow use, was investigated by comparing the mean daily post-trap movement of animals within the first 5d of trapping to mean movements for the remainder of the tracking session.

### ***3.1.3 Telemetry***

#### ***3.1.3.1 Transmitters and Receivers***

At the beginning of the study, small radio transmitters (24-28 g total mass) (Titley Electronics, BioTelemetry and Sirtrack NZ) were attached to a collar around the neck of animals prior to



**Plates 3.1 Talgoo site during normal dry conditions.**



**Plates 3.2 Talgoo site: ashy plains with a trail of bilby tracks.**



**Plate 3.3 Gravel plain at Ninu site after good rains.**



**Plate 3.4 Road to Dalgyte site after substantial rainfall.**



their release at the site of capture (Plate 3.7). These were < 5% of body mass and had a specified battery life of around 18 mth. They were selected without knowing the level of transmitter performance with respect to receiving range above and below ground. Further, it was unknown initially if animals could accommodate transmitters for that period of time.

Transmitters were attached to adult animals only i.e. those above approximately 800 g body mass. Transmitters performed well but accumulated mud on the upper surface during infrequent wet periods. Once dry, this mud caused minor chaffing on the skin of the neck of some animals.

As a result of these experiences, transmitters of a lower structural profile and overall mass of 10-15 g were used for most of the tracking. These had a field battery life of approximately 2 mth and were removed at the end of the tracking period.

Individuals were then tracked to the burrow occupied each day using Telonics TR2 scanning receivers (Telonics USA) and standard radio telemetry techniques (see White and Garrott 1990). (Note: the bilby is strictly nocturnal and does not change burrows during daylight hours.) The length of the tracking period and hence number of locations obtained depended on time spent at the study site (1-3 months), and was also influenced by transmitter performance, weather and losses due to death, predation and dispersal. Animals were re-trapped at the end of the field trip and all collars were removed.

### *3.1.3.2 Antennas*

Different antenna arrays were used during the process of locating animals. Long-range location required the use of higher gain, vertically aligned antennas, with less directionality. These were established approximately 7 m above ground level. Once the approximate location was obtained, horizontally aligned, directional antennas were used in pinpointing precise location.

#### 1. Burrow use and burrow range

Burrows used by individual bilbies during daylight were located each day following their release from trap sites. These daily locations continued for as long as possible (up to 6 wk within the 1-3 mth at the study site).

Minimum convex polygons were constructed from diurnal locations of occupied burrows to provide an index of what could be considered a minimum area of activity or a minimum home range. I have termed this a 'burrow range'. Polygons were constructed from consecutive day locations of animals over the tracking period. Many factors including weather, transmitter performance, animal dispersal and predation influenced not only the length of the tracking period but also the continuity of the data set.

A vertically aligned five-element folded dipole yagi antenna (Sirtrack, NZ.) mounted on a collapsible tripod 5 m above the roof rack of the vehicle was used to detect animals at long range with little directional resolution (see Plates 3.5, 3.6 and 3.7). Once animals were located in this fashion a pole-mounted (rotatable) horizontally aligned H frame antenna supported outside the driver's side window of the vehicle was used to obtain directionality. Final determination of the burrow location was completed on foot using a hand-held horizontally aligned three-element folded dipole yagi (Sirtrack).

## 2. Home range

Fixed-station tracking was conducted at Dalgyte site in August 1992 using 5 m towers mounted on the top of the canopies of two Toyota Landcruiser utilities. A single, directional, seven-element yagi antenna was mounted to the top of the tower. The whole assembly was rotatable and a compass rose, needle pointer and receiver were located in the back of an enclosed canvas canopy of the vehicle. The two vehicles were located 700 m apart, with communications provided to each by hand-held UHF radios.

Control transmitters (2) were placed at different locations by one observer (unknown to the other) to derive an error component for tracking fixes.

Compass readings (bearings) to each collared animal and the control transmitters were taken simultaneously by each observer approximately half-hourly throughout the night for five nights.

### **3.1.4 Burrow activity status**

Individuals were located in their diurnal burrows using telemetry, and a score of burrow activity was then allocated. Burrows were assigned a two digit score based on 'mound condition' and 'tracks' (see Table 3.1). A mound condition score of 4,3 or 4,4 indicated maximum sign of bilby activity at the burrow.

**Table 3.1 Assessment criteria used when scoring activity of burrows.**

<b>Score</b>	<b>Description</b>
<b>Mound condition</b>	
0	No evidence at all i.e. no soil disturbance or excavation.
1	Soil disturbance in the immediate vicinity of the entrance only - no excavation.
2	Fresh excavation of soil in the immediate vicinity of entrance.
3	Fresh excavation and/or disturbance of soil in an axis extending away from the entrance for less than 50 % of the mound.
4	Same as 3 only for greater than 50 % of the mound.
<b>Tracks</b>	
0	No tracks of any species present.
1	Tracks present but not discernible.
2	Tracks of another species present.
3	Bilby tracks present as well as tracks from another species.
4	Only bilby tracks present.



**Plate 3.5 Antenna set up for initial mobile location of bilbies.**



**Plate 3.6 Hand tracking bilbies at Talgoo site.**



**Plate 3.7** *Macrotis lagotis* fitted with a radio collar.



**Plate 3.8** Radio tracking of *Macrotis lagotis* at Dalgyte site, using vehicles as fixed stations.

### **3.1.5 Data analysis**

All spatial data were mapped and analysed using MapInfo. Statistical comparisons of movements, home range, and numbers of burrows used by the two sexes at different times were carried out using the appropriate parametric or non-parametric tests available in SYSTAT (SYSTAT Inc.1997)

## **3.2 RESULTS**

A total of 26 males and 28 females were tracked over the period of the study.

Time required to locate all animals each day varied between 2 and 8 h depending on the extent and direction of movement from the previous day's location. If animals had moved large distances, the search time increased dramatically, at least initially, due to an inability to predict the direction of movement. On occasions several days were required to locate animals, particularly males that had moved large distances, up to 5 km.

Search times decreased once patterns of movement were recognised.

### **3.2.1 Transmitter performance**

Transmitters from all suppliers generally performed well. If problems in transmitter output were detected animals were re-trapped and fitted with another collar. The range at which animals could be detected underground varied according to transmitter output, substrate and probably depth of individual burrows. Signal strength varied in this manner also. Average below-ground receiving ranges were 200-300 m; however, some burrows attenuated the signal to such an extent that detection range was reduced to less than 100 m. Occasionally, signal strength reduction resulted from the transmitting antenna fracturing and subsequently breaking off, probably as a result of constant rubbing against rocks in the close confines of particular burrows. Above-ground receiving ranges at night varied between 3 and 6 km.

### ***3.2.2 Impact of trapping on movement***

It is not known whether collar wearing inconvenienced animals that were assumed taken by dingos or cats; however, the recapture data revealed no impact of wearing collars in all but a few minor cases. In one instance a collar was found and it was assumed the animal was dead, however, the animal was re-trapped (without its transmitter) on the next trip.

Animals frequently did not use the burrow at the site of trapping again: 63% of females (n = 27) and 71% of males (n = 21).

The means for each day of the first 5 d of post-trap movement were compared with the means for the remainder of the tracking period to see if there were any significant effects of trapping (Fig 3.2). The first 2 d of post-trap movements made by males and the first day for females were greater than the means of the remaining movements for the tracking period (Wilcoxon signed rank tests,  $z = 1.965$  males,  $z = 2.201$  females;  $p < 0.05$ ). These data were therefore removed from further analysis of burrow range and movement patterns.

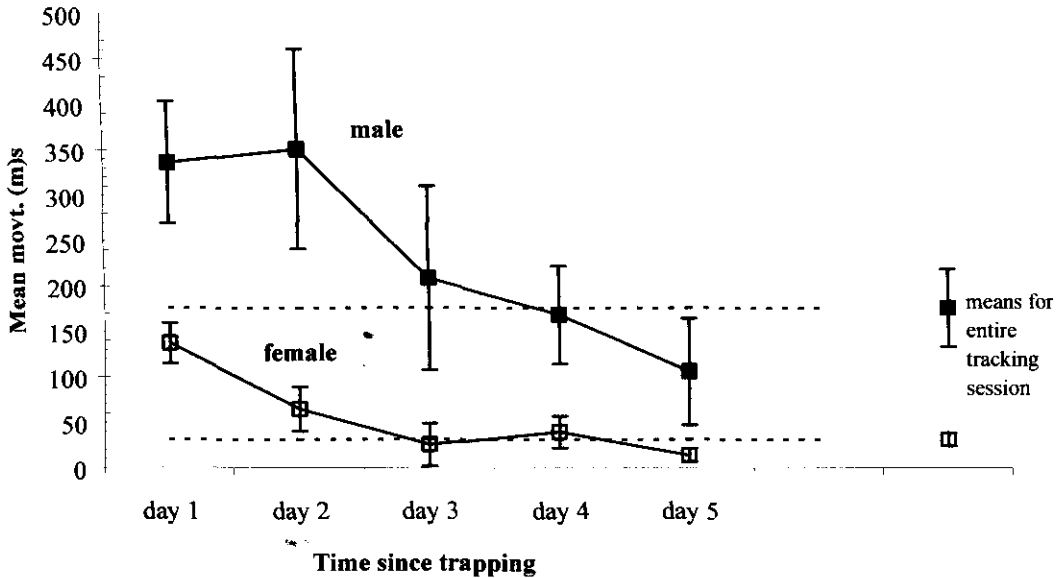
Males made post-trap movements more frequently than females and the distances were significantly larger (Table 3.2).

Of the females, 25 % showed no movement in the first 2 days following trapping compared with 4 % for males.

### ***3.2.3 Burrow use and movement***

All data were standardised by the number of locations found over 21 days so that meaningful comparisons between sexes could be made. In a few instances an animal was unable to be located on a particular day for a variety of reasons. In these cases no movement to, or from, the 'location' could be assigned so the data were not included in the analysis. In these few cases it is unknown whether burrow ranges were under or over estimated. Intuitively one might assume an underestimate, since if you cannot find the animal, it is likely to have moved out of range and you will thus have missed a large movement event. This is not necessarily the case, however, since the animal might be occupying a particularly deep burrow in which the signal strength is severely attenuated and thus is not able to be picked up except at very close

range. Further, many of the cases of missed days were as a result of heavy rainfall, which prevented access to the study sites. In these cases one could reasonably expect that animal activity and movements would also be limited. It is thus not unreasonable to suggest an overestimate, as a result of the missing data i.e. the animal hasn't moved at all.



**Fig. 3.1 Mean ( $\pm$  s.e.) daily movement (m) of animals following a trapping event (n = 26 males, 28 females)**

A summary of the results obtained is presented in Table 3.2. Non-parametric Mann-Whitney tests were used to determine the significance of differences between sexes. These data were obtained from adult males and females from Dalgyte, Talgoo and Ninu sites during 1992 and 1995-1997. The data set includes only adult animals with more than 10 days of location data available. Juvenile animals were not included in the data set since sample sizes (number of locations) were small and no apparent differences between sexes were observed - both sexes used few burrows and did not move far from them. The female data only include animals with pouch young since the majority of females sampled had either one or two pouch young.



**Table 3.2 Summary of burrow use and movements between burrows for *Macrotis lagotis* at Astrebla Downs National park. (mean  $\pm$  s.e., n = 357 locations for males, n = 345 for females).**

	Male (n=18)	Female (n=16)	U	p
Number of burrows used	7.2 $\pm$ 0.7	3.6 $\pm$ 0.3	24	***
Number of movements	8.8 $\pm$ 0.8	3.3 $\pm$ 0.4	24.5	***
Mean distance between burrows used (m)	435.2 $\pm$ 41.4	187.6 $\pm$ 27.7	20.5	***
Mean daily movement (m)	189.2 $\pm$ 30.6	36.2 $\pm$ 7.8	13	***
Total number of locations (d)	345	357		
Mean number of locations (d)	19.8 $\pm$ 1.9	21.6 $\pm$ 2.6		

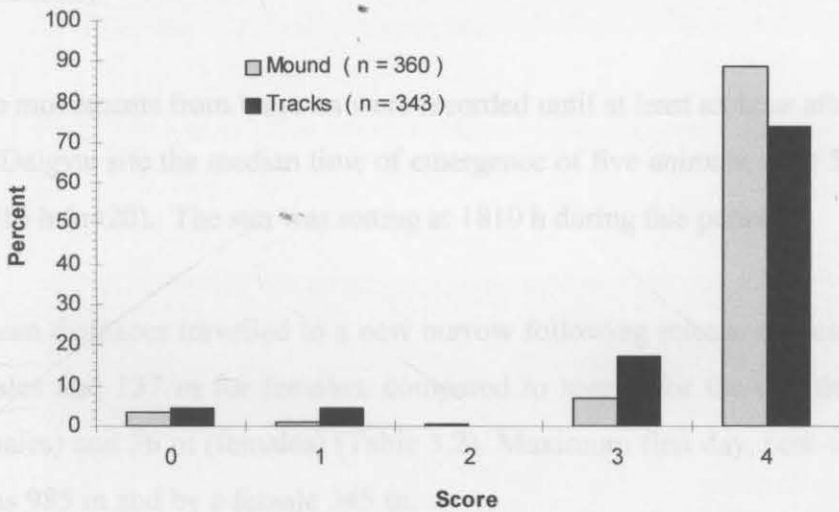
Means standardised for 21 days of locations. (\*\*\*) p < 0.001, Mann-Whitney U test.)

Mean daily movement in Table 3.2 was calculated as the mean of all movements and includes locations where no movement was recorded i.e. animal was in the same burrow as the previous day. However, the mean distance between burrows used excludes zero movements and thus provides a spatial indication of all the burrows used rather than a temporal indication of movements.

Overall, 62.1% of females and 45.9% of males used only one or two burrows during the study period; 7% of females used greater than four burrows (max 7); 46% of males used greater than four burrows (max 11).

Of the individuals tracked, one male (4.2%) and twelve females (41.4%) used a single burrow over the entire tracking period. In these instances where an animal remained at the same location over a number of days, inspection of use of the burrow was carried out. Burrow scores of mound condition and tracks assisted interpretation in this regard, however, if concerns existed as to the animal's health, telemetry location at night was

carried out to confirm the situation (mortality sensors were not included in transmitter packages). The results for activity occurrence on burrow mounds are shown in Fig.3.2. These data suggest that a mound with freshly disturbed and/or excavated soil and bilby tracks indicated the presence of an animal in a burrow, approximately 90% of the time. Burrows showing extensive evidence of bilby presence (score of 3,4 or 4,4), and little or no evidence are shown in Plates 3.8, 3.9. Each had a radio-collared bilby present at the time. Animals were recorded sharing the same burrow on five occasions. In one instance two adult females shared the same burrow complex for five days; both had pouch young. The four other occasions were male/female sharing and in one instance the female was unbred, the other three females had pouch young at the time of sharing with the male.



**Fig. 3.2 Mound condition and occurrence of bilby tracks on burrows known to have a radio located bilby present.** (A track score of 3 or 4 indicates bilby tracks present. Refer to Table 3.1 for interpretation of score value).

### 3.2.4 Burrow range

The burrow trap sites of animals were not used in calculating burrow ranges and assessing movement patterns. These burrows were excluded from the analysis since they reflected a chance encounter with animals during spotlighting at night and some retreated to the nearest

burrow rather than one 'known' or 'preferred' by them. That this was the case is indicated by the fact that 63% of females and 71% of males didn't use the burrow where they were trapped, for the remainder of the tracking period (3.2.2).

A minimum of 10 daily locations was used to construct burrow ranges, since sample sizes less than 10 days were too small, given the post trap movements made by animals during the first 1-2 days after release. Further, shorter periods of location often meant that troubles with transmitters or animals were experienced, and hence data were not considered reliable. Mean number of consecutive day locations for males was  $19.8 \pm 1.9$  d (mean  $\pm$  s.e., range 11-35 d, n=18, 357 locations); and for females,  $21.6 \pm 2.6$  d (range 10-42, n=16, 345 locations).

No movements from burrows were recorded until at least an hour after sunset. In August 1992 at Dalgyte site the median time of emergence of five animals, over 5 nights of telemetry, was 1915 h (n=20). The sun was setting at 1810 h during this period.

Mean distances travelled to a new burrow following release at their trap site was 336 m for males and 137 m for females, compared to means for the duration of tracking of 189 m (males) and 36 m (females) (Table 3.2). Maximum first day, post-trap movement by a male was 985 m and by a female 345 m.

Burrow ranges for a selection of the tracking sessions are presented in Figs 3.3, 3.4, 3.5 and 3.6. Burrow ranges for individuals with burrow use histograms attached are shown in Figures 3.7, 3.8, 3.9 and 3.10.

Mean burrow ranges in ha for males,  $15.3 \pm 4.6$  (mean  $\pm$  se; n=10) were larger than ranges for females,  $3.0 \pm 0.8$  (n=11) (Mann-Whitney U = 15;  $p < 0.01$ ).

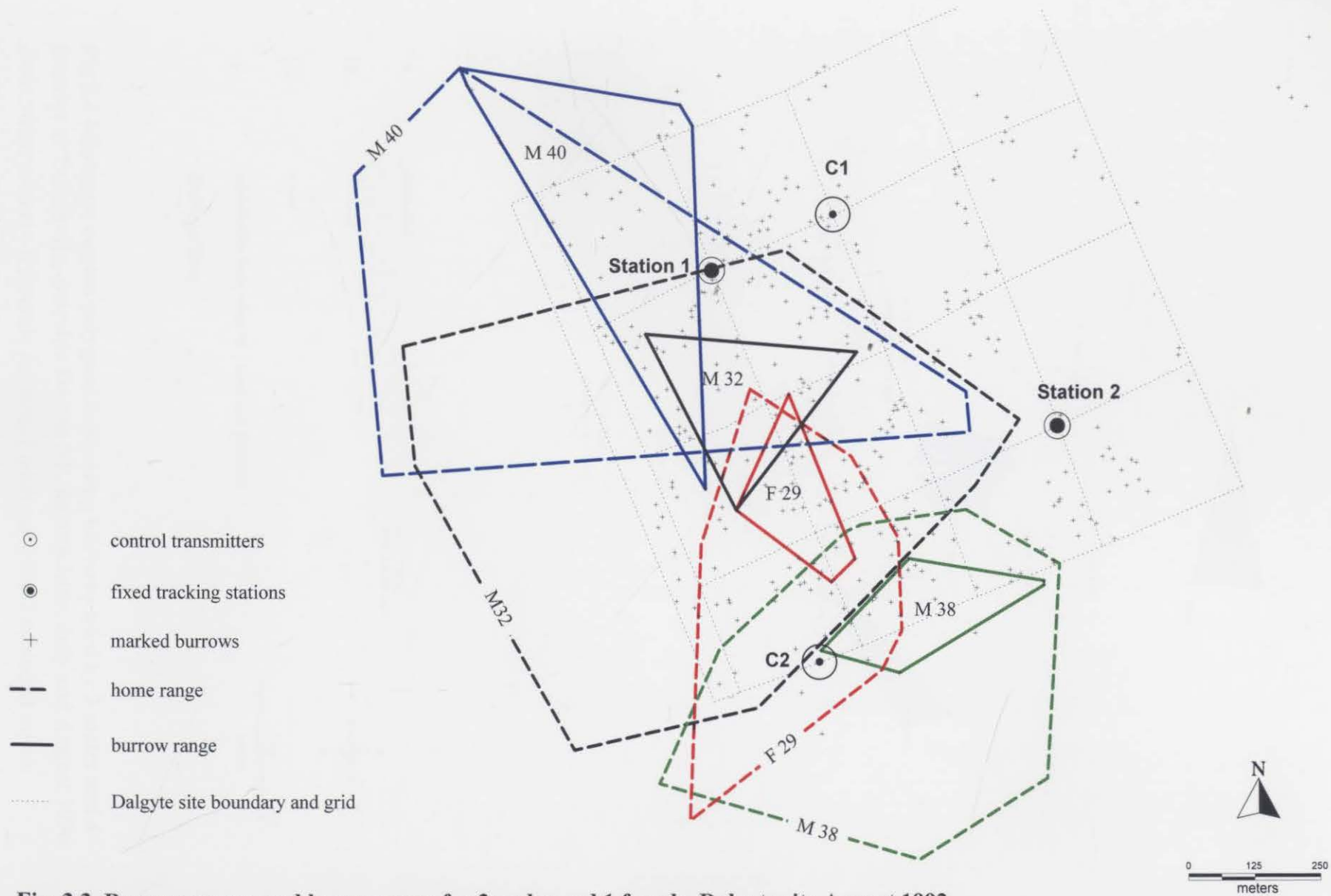
Burrow range sample sizes were small, particularly for females since many individuals used only one or two burrows and thus a burrow range polygon could not be constructed.



**Plate 3.9 Active bilby burrow with a radio collared bilby present.**

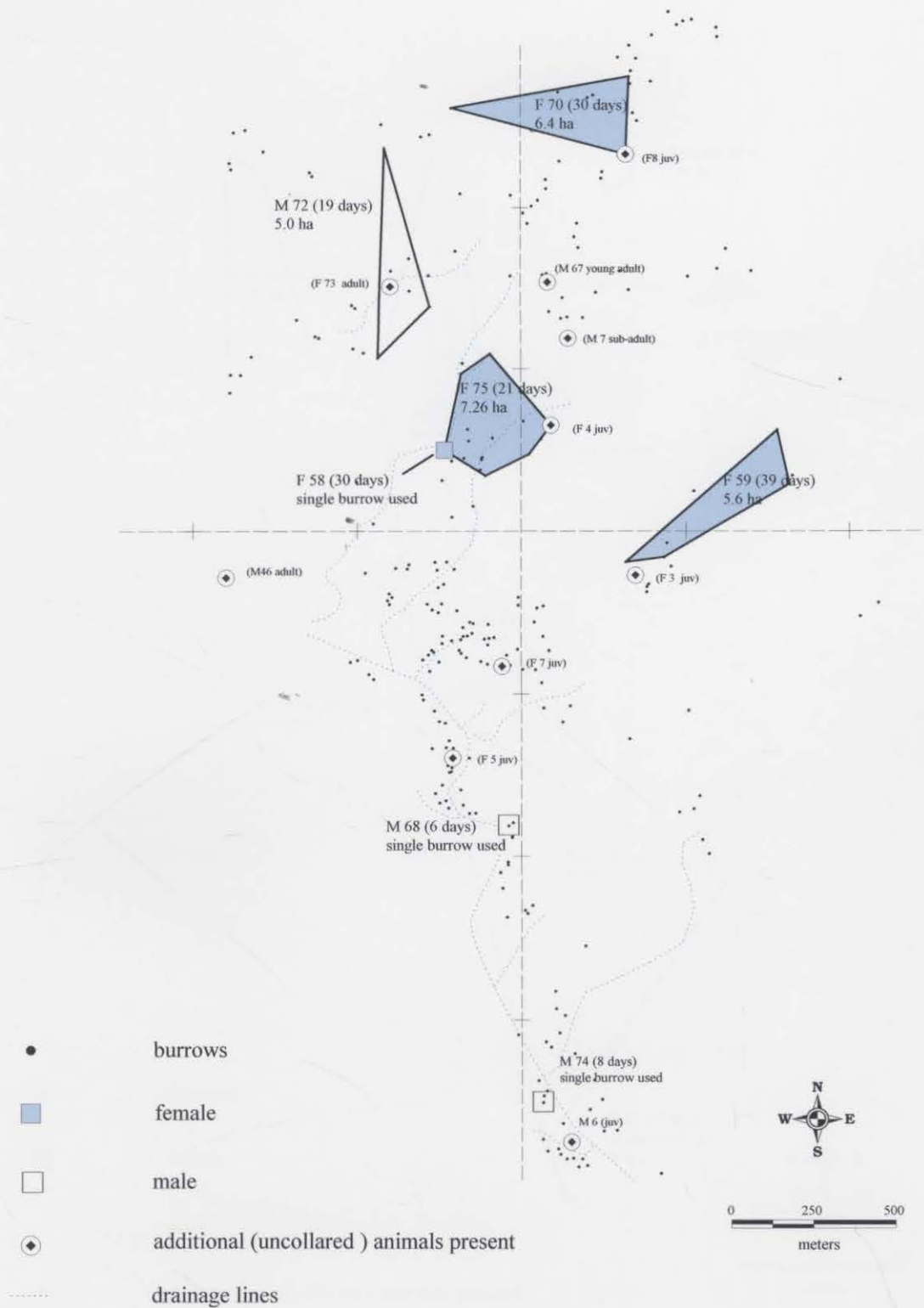


**Plate 3.10 Burrow with a radio collared bilby present, but no active sign.  
(after rain deluge over night)**



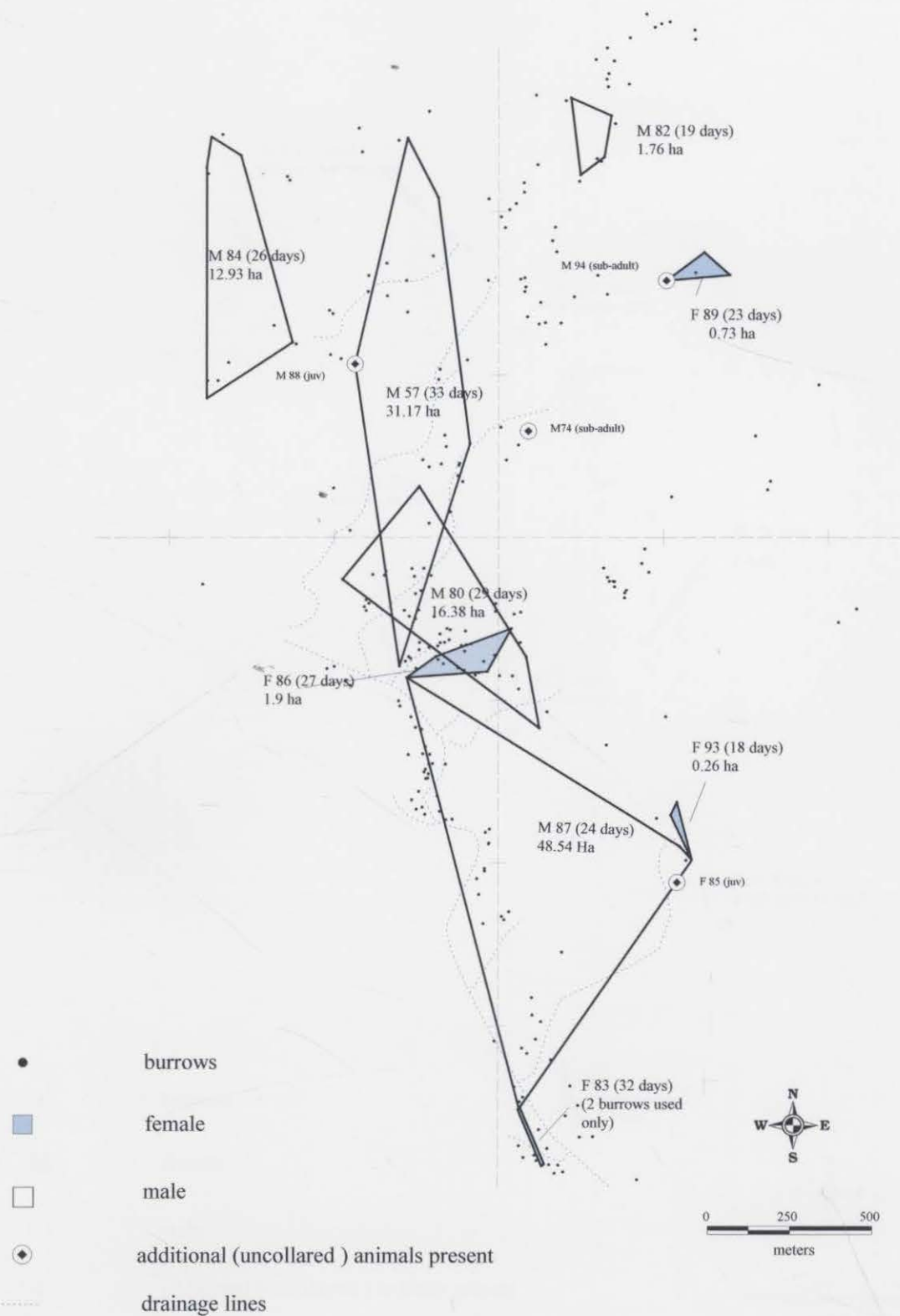
**Fig. 3.3 Burrow ranges and home ranges for 3 males and 1 female. Dalgyte site August 1992.**  
**Note : 15 animals known to be alive in the site area.**





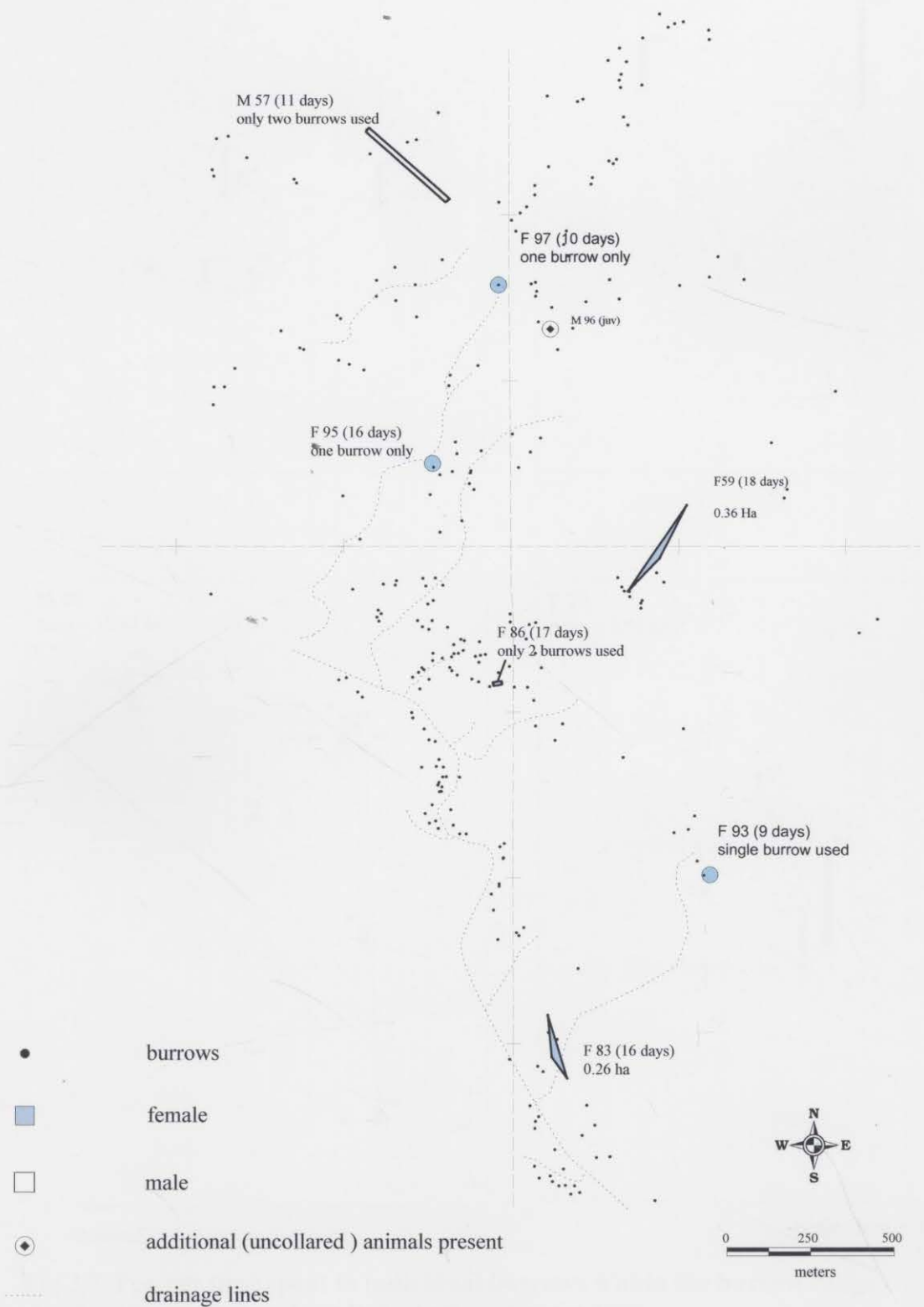
**Fig 3.4 Minimum convex polygons delineating burrows used by 3 males and 4 females at Talgoo site, Astrebla Downs NP, during June, July and August 1996.**

Note : Also present - 6 juvenile females, 1 adult male and 2 sub-adult males.



**Fig 3.5 Minimum convex polygons delineating burrows used by 5 males and 4 females at Talgoo site, Astrebla Downs NP, during April and May 1997.**

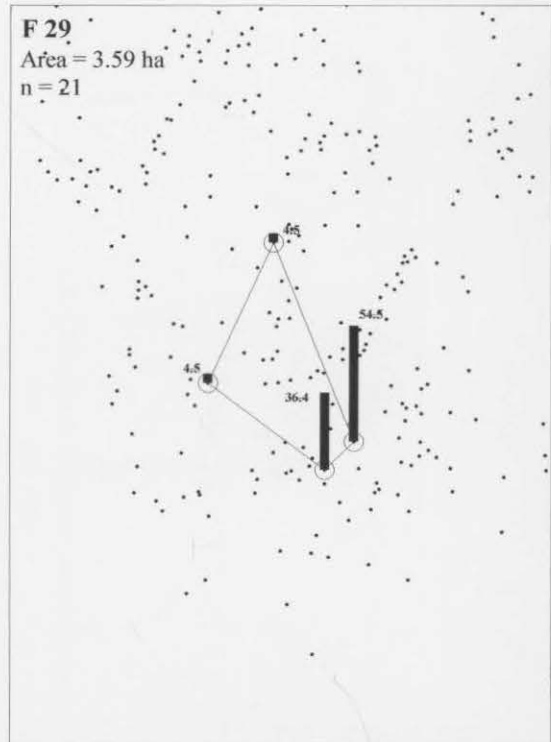
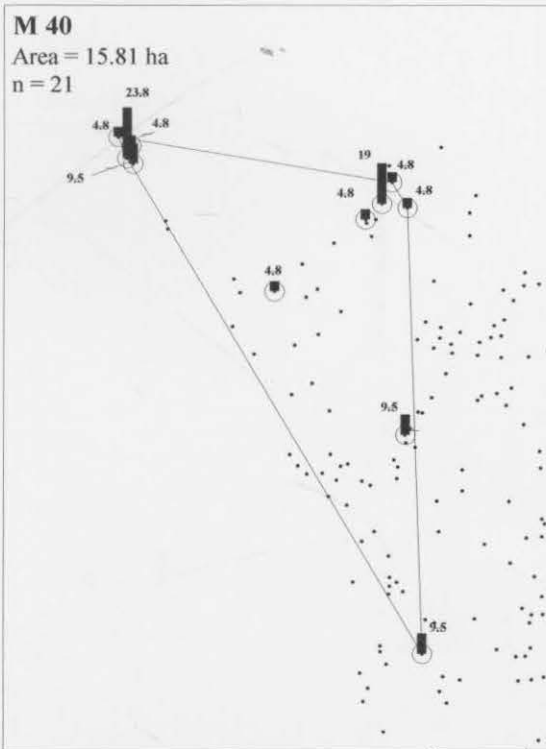
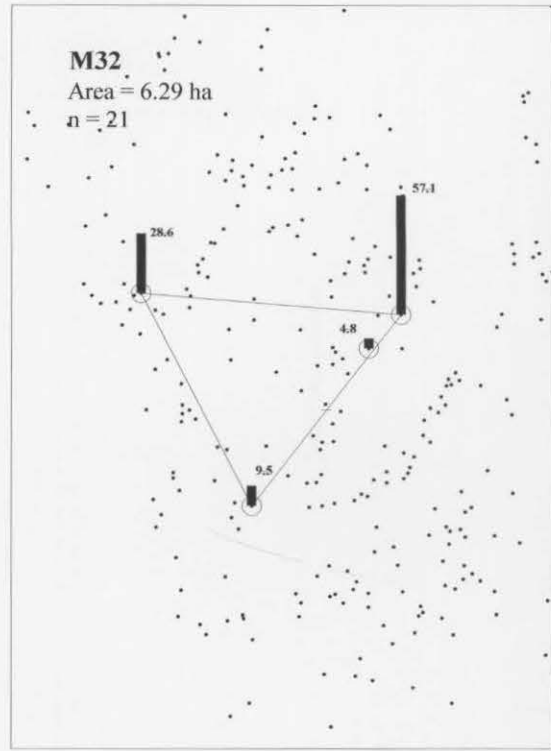
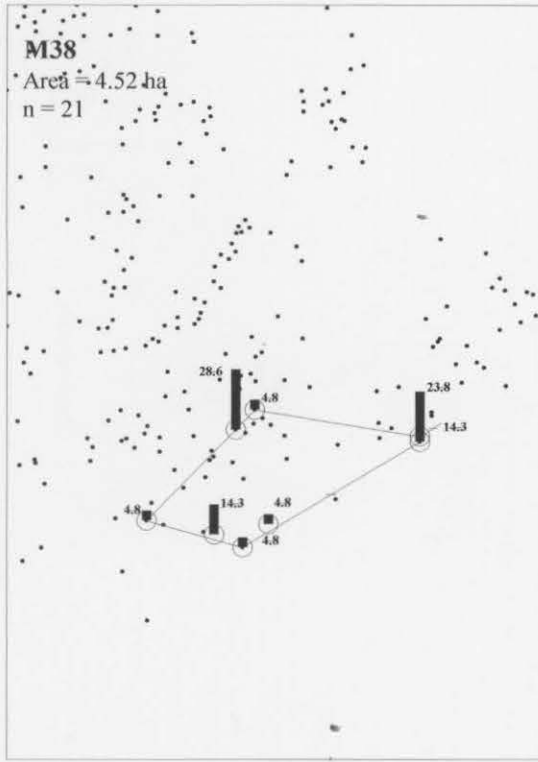
Note : Also present -2 sub-adult males, a juvenile male and juvenile female.



**Fig 3.6 Minimum convex polygons delineating burrow ranges for a male and 6 females at Talgoo site, Astrebla Downs NP, during September 1997.**

Note: uncollared animals also present.





• Additional marked burrows in the area.

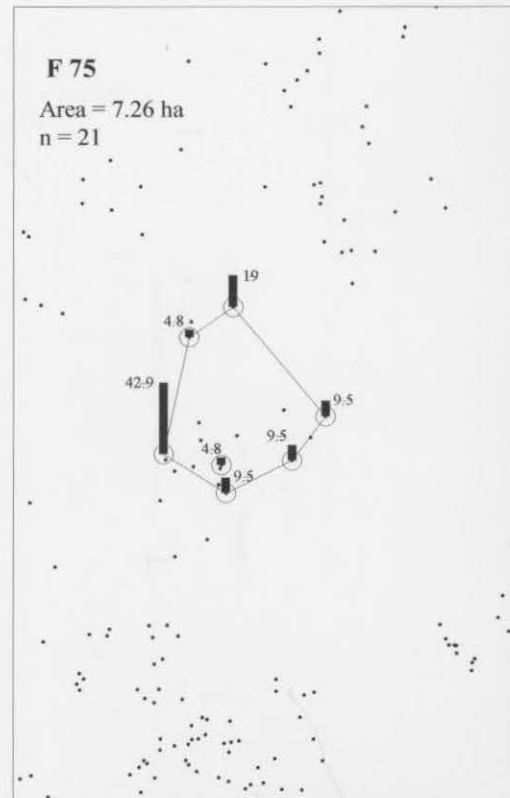
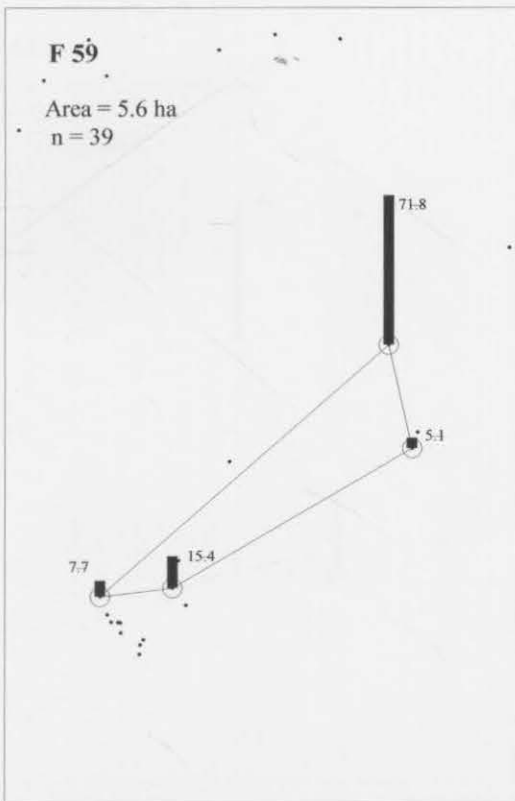
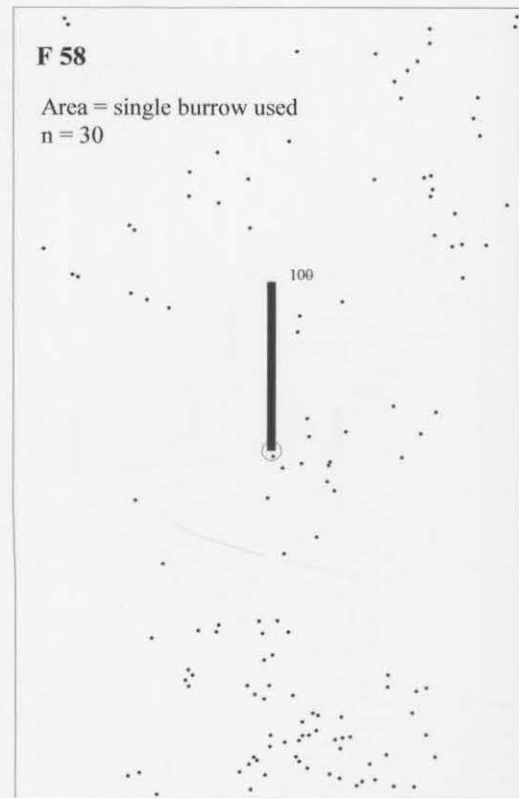
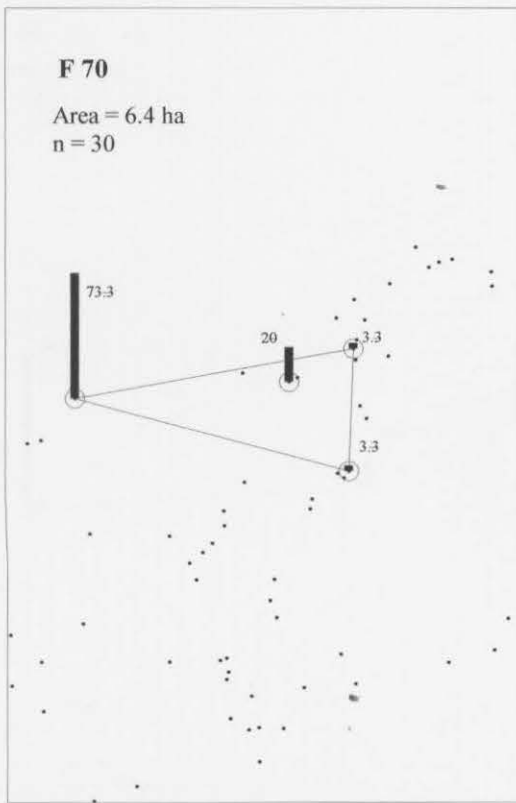
Scale : 1cm = 116 m

**Fig 3.7 Percent time spent in individual burrows within the burrow range for 3 males and a female at Dalgyte site, August 1992.**

The numbers attached to individual columns indicate percent time in that burrow.

\* n = the number of consecutive day locations.

\*\* area = area in ha of minimum convex polygon.



+ Additional marked burrows in the area.

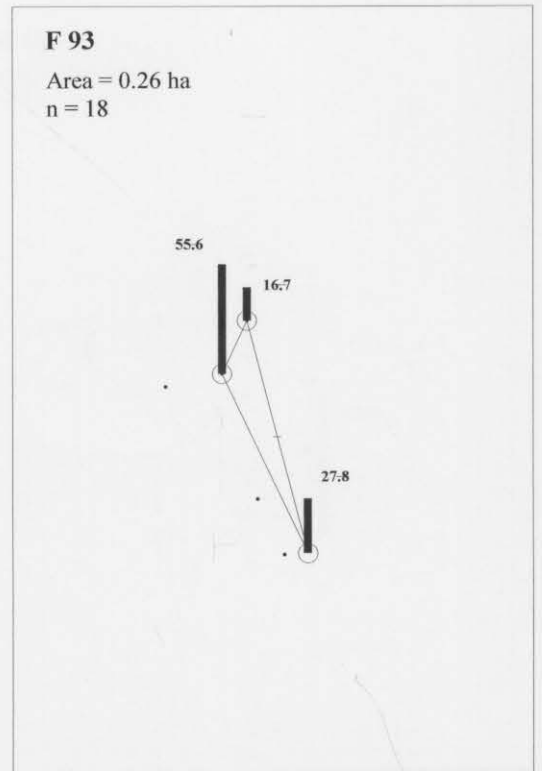
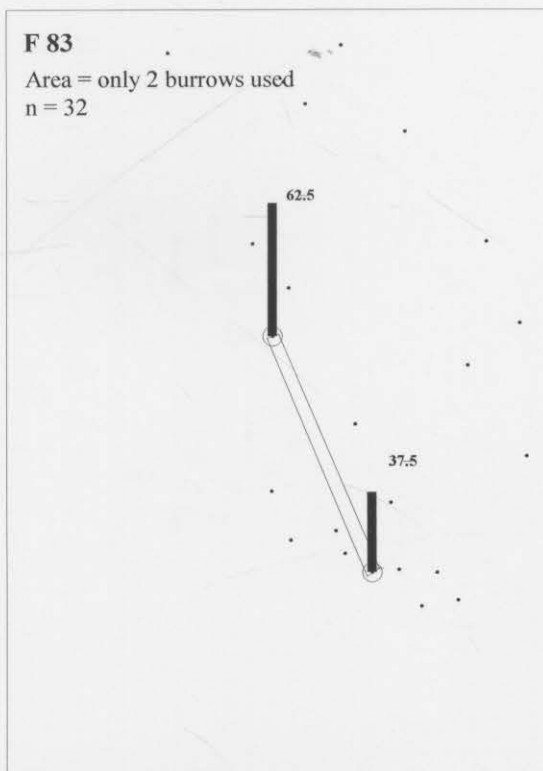
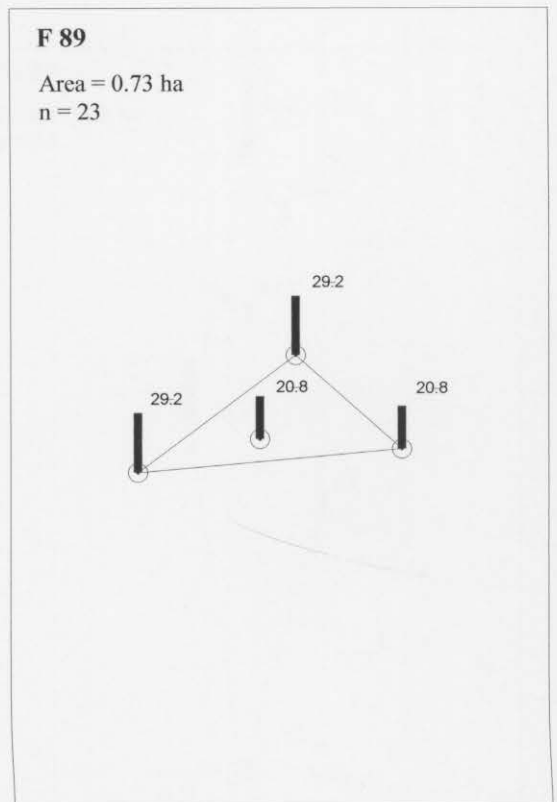
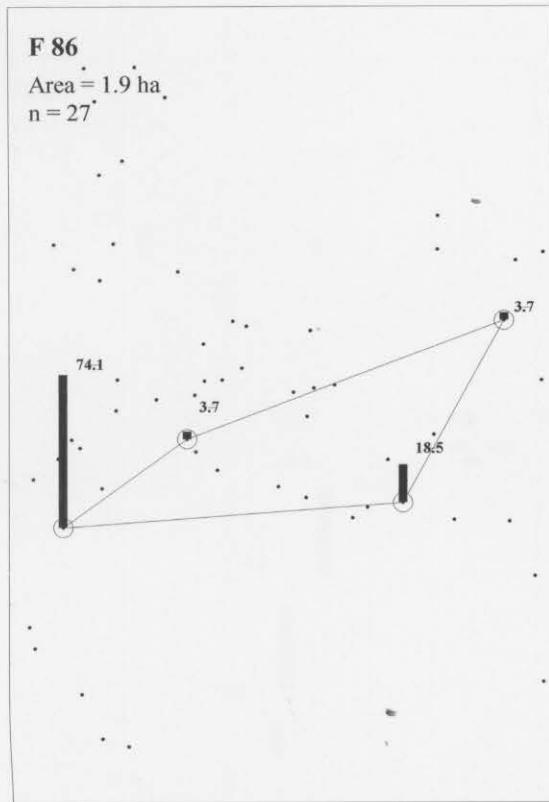
Scale : 1cm = 139 m

**Fig 3.8 Amount of time (percent) spent in individual burrows within the burrow rang for 4 females at Talgoo site , June - August 1996.**

The numbers attached to individual columns indicate percent time in that burrow.

\* n = the number of consecutive day locations

\*\* area = area in ha of minimum convex polygon.



+ Additional marked burrows in the area.

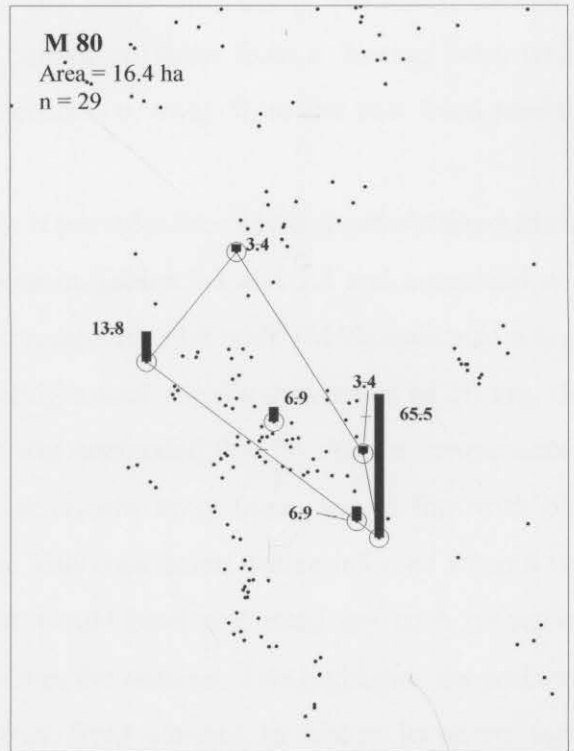
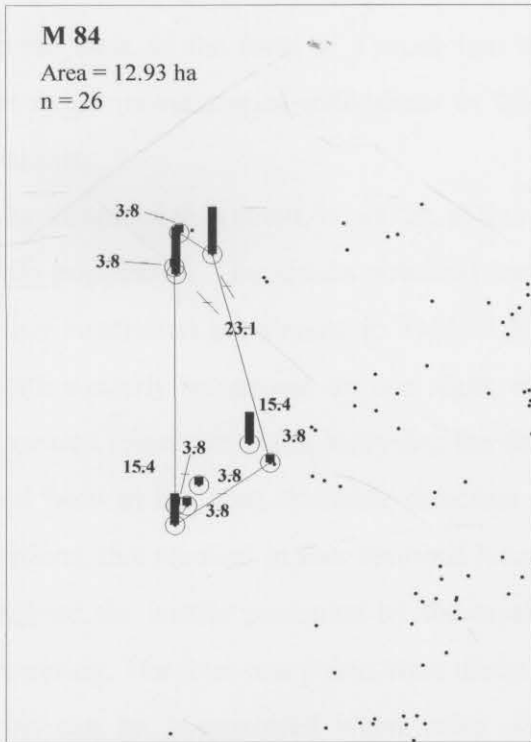
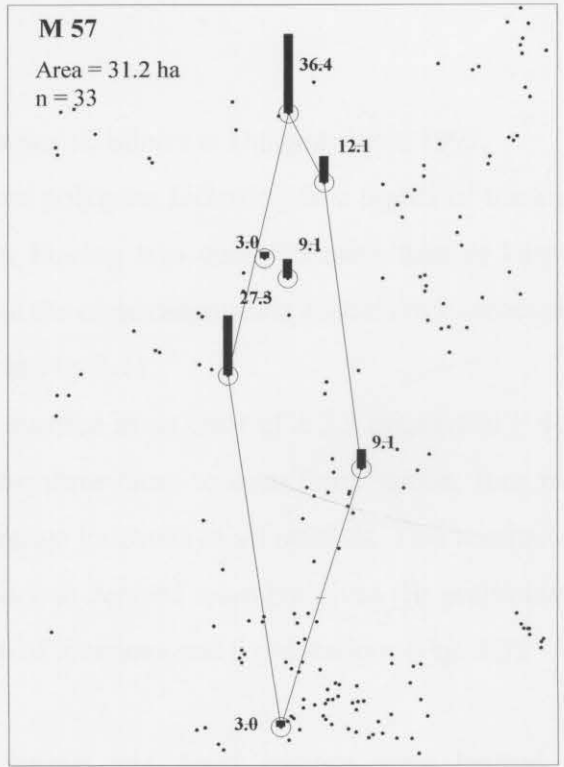
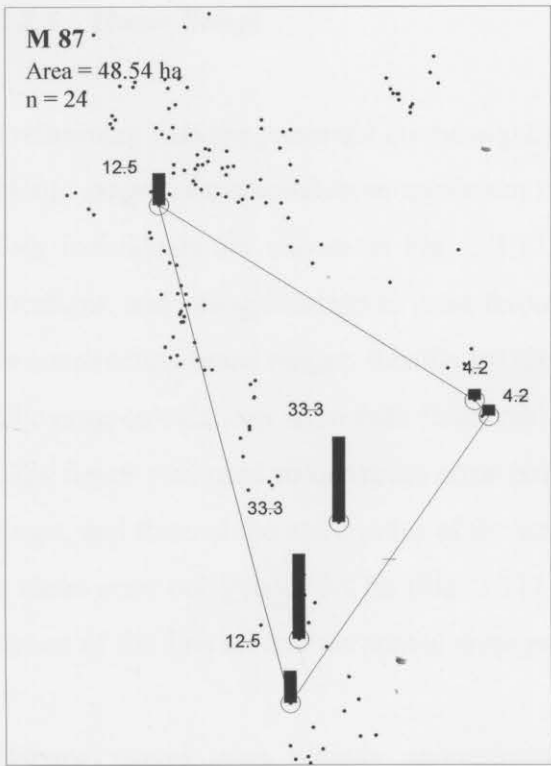
Scale : 1 cm = 55 m

**Fig 3.9 Amount of time (percent) spent in individual burrows within the burrow range for 4 females at Talgoo site , April- May 1997.**

The numbers attached to individual columns indicate percent time in that burrow.

\* n = the number of consecutive day locations

\*\* area = area in ha of minimum convex polygon.



• Additional marked burrows in the area.

Scale : 1cm = 200 m

**Fig 3.10 Amount of time (percent) spent in individual burrows within the burrow range for 4 males at Talgoo site, April- May 1997.**

The numbers attached to individual columns indicate percent time in that burrow.

\* n = the number of consecutive day locations

\*\* area = area in ha of minimum convex polygon.

### 3.2.5 Home Range

Preliminary data are presented on the nightly ranging of bilbies at Dalgyte site in 1992.

Home ranges constructed from minimum convex polygons following five nights of tracking four individuals are shown in Fig. 3.3 (3.2.4). Placing two control transmitters at known locations, and taking bearings to these throughout the night determined spatial error associated in constructing home ranges. Results are shown in Fig. 3.11.

The error calculations from both fixed stations resulted in an error of  $\pm 3.5$  degrees ( $n = 41$ ). This figure was used to construct error polygons: three close to each fixed station, four mid range, and three at the extremities of the home range locations of all animals. This resulted in a mean error polygon of 0.8 ha (Fig. 3.11). This was deemed tolerable given the preliminary nature of the data set and the spatial arrangement of locations and fixed stations (Fig. 3.3).

Burrow ranges were already approximately known and fixed stations were located to accommodate these known day locations of animals. Particularly useful was a physical barrier to the west, in the form of a creek line with permanent water from a flowing bore, which restricted movement of individuals in that direction i.e. away from the two fixed tracking stations.

The sample size is small, however, at this stage it provides the only data set obtained from a wild population. The results obtained are shown in Tables 3.3 and 3.4 and compared with other Australian bandicoots in Table 3.5. The results for one male (M40) indicated a large north-westerly movement on one night, indicating a total night's movement of 20 km, that appeared excessive. After analysing the data it was concluded that, by chance the movement had been in the least desirable direction i.e. movement away from, and in line with both stations, that resulted in four spurious locations. This conclusion was re-inforced when it was realised the barrier presented by the creek line would have prevented any such movement occurring. The four data points were discarded from the analysis. This highlights the problems than can be encountered when using only two fixed stations to obtain locations using triangulation (see White and Garrott 1990, Harris 1990).

Table 3.3 Home range of three males and a female bilby over five nights at Dalgyte site, June 1992.

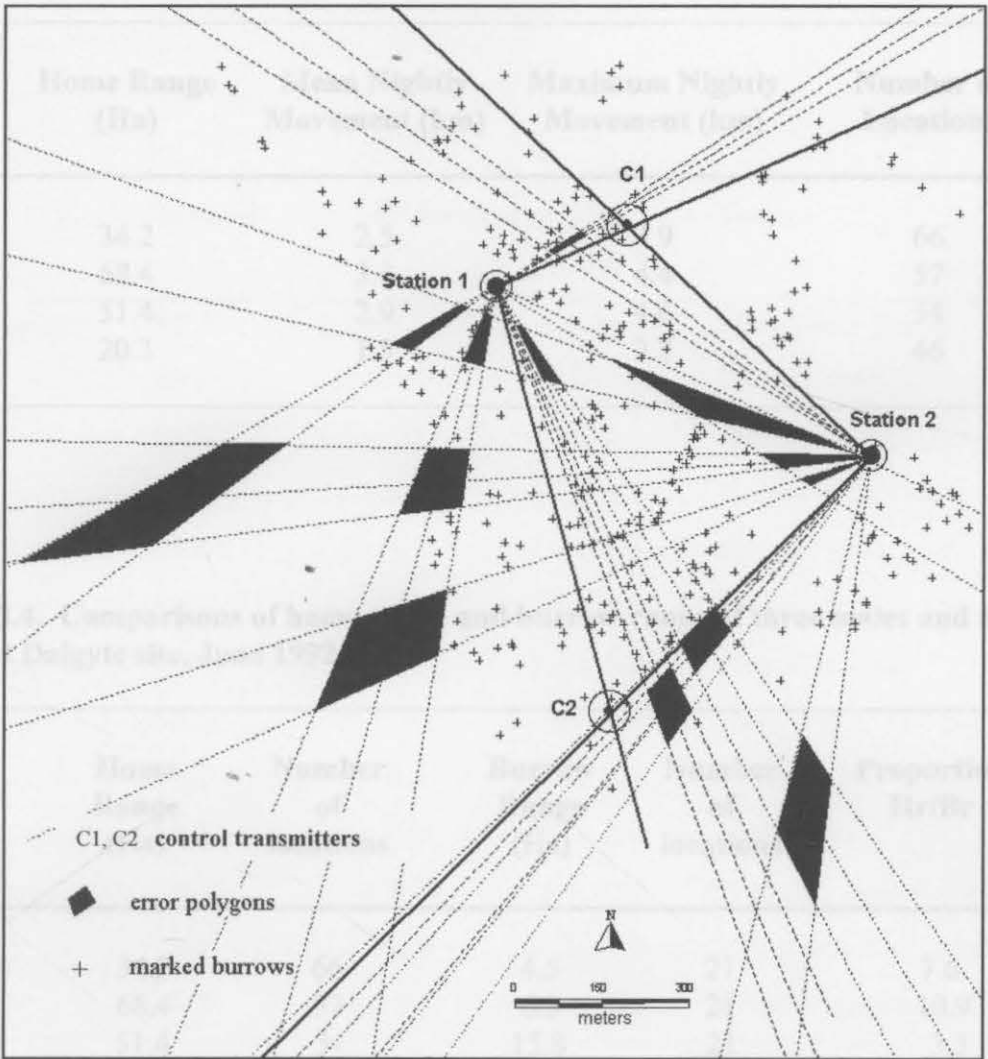


Fig. 3.11. Error ranges for fixed station tracking of home range at Dalgyte site, June 1992. (See Fig. 3.3 for site context of these locations)

**Table 3.3 Home range of three males and a female bilby over five nights at Dalgyte site, June 1992.**

	<b>Home Range (Ha)</b>	<b>Mean Nightly Movement (km)</b>	<b>Maximum Nightly Movement (km)</b>	<b>Number of Locations</b>
M 38	34.2	2.5	3.9	66
M 32	68.4	3.4	4.4	57
M40	51.4	2.9	4.6	54
F23	20.3	1.5	2.2	46

**Table 3.4. Comparisons of home range and burrow range of three males and a female bilby at Dalgyte site, June 1992.**

	<b>Home Range (Ha)</b>	<b>Number of locations</b>	<b>Burrow Range (Ha)</b>	<b>Number of locations</b>	<b>Proportion Hr/Br</b>
M 38	34.2	66	4.5	21	7.6
M32	68.4	57	6.3	21	10.9
M40	51.4	54	15.8	21	3.3
F23	20.3	46	3.6	21	5.6

These data indicate maximum movement in a night of nearly 5 km for a male, and 2.2 km for a female. As would be expected, this distance travelled during a night of foraging, is much greater than the mean distance between burrows used (435m for males; 188 m for females. Table 3.2)

**Table 3.5. Comparison of home range sizes (mean  $\pm$  s.e.) for a number of bandicoot species.**

Species	Method	Home Range (Ha)		Source
		Male	Female	
<i>Isoodon obesulus</i>	MCP	5.3 $\pm$ 0.5	2.3	Heinsohn 1966
<i>I. obesulus</i>	HM	1.8 $\pm$ 0.7	1.1	Lobert 1990
<i>I. obesulus</i>	MCP	2.3 $\pm$ 0.2	1.8 $\pm$ 0.2	Broughton and Dickman 1991
<i>I. o. nauticus</i>	GCP	2.1 $\pm$ 0.3	1.5 $\pm$ 0.2	Copley <i>et al.</i> 1990
<i>Isoodon macrourus</i>	MMA	2.8 $\pm$ 1.7	1.9 $\pm$ 1.4	Gordon 1974
<i>Isoodon auratus</i>	MCP	15.6 $\pm$ 4.7	6.2 $\pm$ 2.3	Southgate <i>et al.</i> 1996
<i>Perameles gunnii</i>	MCP	26.3 $\pm$ 4.6	3.2 $\pm$ 1.1	Heinsohn 1966
<i>P. gunnii</i>	MCP	12.9 $\pm$ 7.3	2.4 $\pm$ 1.4	Dufty 1991
<i>P. gunnii</i>	MCP	4.0 $\pm$ 0.6	1.6 $\pm$ 0.4	Dufty 1994
<i>P. nasuta</i>	MCP	4.4 $\pm$ 0.8	1.7 $\pm$ 0.1	Scott 1995
<i>Macrotis lagotis</i>	MCP	31.6 $\pm$ 1.28	1.8 $\pm$ 0.04	*Moseby and O'Donnell 2003
<i>M. lagotis</i>	MCP	51.1 $\pm$ 0.8	20.3 $\pm$ 0.8	Home range this study
<i>M. lagotis</i>	MCP	15.3 $\pm$ 4.6	3.0 $\pm$ 0.8	Burrow range this study

(MCP -minimum convex polygon; HM – harmonic mean; MMA – modified minimum area; GCP – grid cell plots).

\* re-introduced animals constrained within a 14 km<sup>2</sup> predator free enclosure.

### 3.3 DISCUSSION

#### 3.3.1 Trapping

Individuals in the wild population of bilbies studied were unwilling to enter wire cage traps, despite the lure of many types of bait attractants offered. This is possibly related to the



habitat i.e. flat, open and sparsely vegetated plains, where a trap could be considered a relatively major visual intrusion in the landscape. The spotlighting and trapping procedure employed also presented sampling problems, being more physically exhausting and time demanding, compared to the effort and returns obtained for many other species from laying trap grids. The trapping technique used is, however, still the most effective way of capturing animals in this landscape.

It suffers from a reliance on chance encounters whilst spotlighting at night, which requires good visibility and suitable densities of animals. Moreover, it was disruptive in that lengthy periods of time (up to 5-7 h) had to be spent on site at night to procure only one or two animals. Further disruption occurred when setting the trap, as soil was redistributed to block escape routes and allow level placement of cage traps in the fence panels. Even though reconstruction of the trap site and burrow mounds was conducted when the trap was removed, the immediate surrounds of the trap site area remained obvious and quite disturbed.

The trapping procedure used failed to capture any females with large pouch young (fully furred, with eyes open). I suggest that this is behaviourally related, perhaps reflecting limited movements of females with large pouch young near burrows, and affected encounter rates, since juveniles were observed throughout the study period. Moseby and O'Donnell (2003) reported infrequent recapture of females with large pouch young in their re-introduced population.

Females at this stage of their lactation are probably physically impaired in terms of mobility and possibly behaviourally susceptible to any form of disturbance, and are thus not encountered. Females did occasionally eject pouch young whilst in the trap, and then often ate part of the body. Even in these instances, however, the young were still in the early to mid stages of their development. During this time females must be able to accommodate the increased demands of lactation, requiring increased food resources, and a depressed physical mobility to do so. Inhabiting areas where food resources are not limiting is thus critical (Gibson 2001, Gibson and Hume 2000).

Trapping procedures were improved over the duration of this study, as is evidenced by the increasing trap success rates. This could be further improved by having a mechanism that

alerts the observer when a trap is sprung – this would minimise any interference and resultant stress caused by visiting predators and further, reduce stress-related damage to the animal (damaged teeth, skinned snouts, ejecting pouch young) as a result of being in a trap.

Any studies of spatial organisation and movement patterns based on trapping animals should account for the range of issues raised in the present work.

### **3.3.2 *Burrow use***

Individual bilbies used a number of burrows over the tracking periods of 4-6 weeks in 1992 and 1995-1997. Males used twice as many burrows as females and the mean distance between burrows on successive days was five times larger for males. Males often made large movements on successive nights to a new diurnal resting burrow. The largest recorded movement was 2.2 km, which is slightly less than that recorded by Southgate (R. Southgate pers. comm.) and Moseby and O'Donnell (2003) in re-introduction studies.

Females showed greater site fidelity than males and displayed significantly less consecutive day movement to a different burrow, and occupied the same burrows for a significantly longer period of time. Site fidelity is probably even stronger than reported here, since chance encounters with predators or other disturbing events, possibly accounted for the infrequent use of different burrows by females, generally as 'bolt-holes' only for a night or two at a time. This type of occupancy could not be attributed to a differential change in food availability in the short time frames considered.

In the broad landscape context, where suitable habitat is defined by the species, strong site fidelity is likely to be selectively advantageous. The study area has a patchy distribution of suitable habitat that includes isolated patches of compacted sandstone outcrops in deep cracking clay soils of the ashy plains, and compacted sandstone slopes along drainage depressions (see Chapter 1). As a natural consequence of this, bilby populations are also patchy and fragmented, resulting in clumped areas being continually used by individuals. These areas appear to be determined by suitable soil structure and stability for burrow construction as well as adequate adjacent food resources, and reflect a long period of

occupation by bilbies, as evidenced by burrows that remain visible in the landscape for long periods of time.

The sites used in this study have shown continued occupancy by bilbies since 1990, though populations have fluctuated temporally with seasons. Burrow vacancies as a result of dispersion or mortality were taken up by other individuals and often by other species as well (P. McRae unpublished records).

Burrows were frequently shared with other species as well as within species. Burrow sharing by males, females and juveniles is possibly more frequent than what Moseby and O'Donnell (2003) briefly referred to, and Johnson and Johnson (1983) observed in a captive behaviour study. One male, M87, visited 3 different females in their burrows during April-May 1997. Such observations are not surprising given the polygynous nature of male bilbies reported by Moritz *et al.* (1997). They demonstrated polygyny using DNA analysis and assigned parentage of 7 of 8 off-spring that could be determined, to a single male (and 3 females) at Talgoo site in the current study area.

### **3.3.3 Home Range and Burrow Range**

Males and females differed in their ranging behaviour and the number of burrows they consistently occupied within their home ranges. The preliminary data on home range indicate that the area of nightly ranging is considerably greater (6-7 times) than that reflected in the spatial distribution of diurnal resting burrows (burrow range). Burrow range is, however, a good relative guide to the areas required for bilbies in this habitat, is more cost effective and easily determined (time wise) than the foraging range, and benefits from precision as well as accuracy.

Burrow range was considered a minimum home range area and could be partly similar to the core area suggested by Kaufmann (1962). A core area was defined as an area used more frequently within a home range and that probably contained home sites, refuges and the most dependable food resource (Samuel *et al.* 1985). Ewer (1968) argued that core areas commonly didn't overlap, whereas home ranges did. In the current study burrow ranges showed minimal,

or no overlap, whereas home ranges showed considerable overlap (see Fig 3.3). However, burrow ranges were probably primarily selected based on soil suitability for burrowing in areas that were adjacent to, or encompassing those that contained adequate food resources.

One problem encountered with the estimation of burrow range was the inability to deal with situations where less than three burrows were used over the tracking period. In these cases constructed burrow range polygons didn't reflect the spatial ranging of individuals, and only indicated their spatial context with respect to other individuals in the study area.

Home ranges determined in this study were greater than those of other bandicoots in Australia (Table 3.5.). This is to be expected since bilbies are currently only extant in the arid zone, where food resources are likely to be more widely distributed and less frequently available. Burrow range is likely to reflect a greater influence of burrow site selection than foraging range, since the available suitable sites for burrows appear to be small in area and patchily distributed. The time spent within individual burrows within the burrow range (Figs 3.7 – 3.10) provides an even clearer picture of site fidelity by indicating burrows that were used infrequently, possibly as a result of disturbance during nightly foraging.

The construction of burrow ranges allows a ready and practical means for identifying what can be considered a minimum home range for a given period. Burrow ranges are no doubt dynamic and the number of burrows used to delineate them is likely to increase with time. That animals continually re-use burrows is evidenced through the almost continual occupation of discreet sites by bilbies between 1989 and the present at Astrebla Downs National Park (personal observations). Temporal rates of occupancy are probably determined by predation rates and environmental factors, such as the shifting availability of food. Southgate (1990 b) suggested predation as a prime regulator of bilby populations. Gibson and Hume (2000) also implicated predators regulating bilby populations, with evidence that food resources were not limiting at Ninu and Talgoo sites in the current study area despite changes in abundance of active burrows. Because populations within the park are fragmented and densities are low, the

importance of these factors can only be quantified by monitoring known sites over long time periods.

Home ranges reported in this study are much greater than those reported by Moseby and O'Donnell (2003), particularly for females (Table 3.5). Their study, however, involved a re-introduction of captive-bred animals into an enclosed area of 14 km<sup>2</sup>. Their study area is sizeable, though only approximately 2.5 km wide, and is thus likely to be restrictive on the normal ranging of individuals. Habitat differences (dunes and swales in South Australia, and flat treeless chenopod plains in Queensland) are also likely to make meaningful comparisons difficult. The results of Moseby and O'Donnell (2003) could be further influenced by the existence of a re-introduced population of similar sized, semi-fossorial burrowing bettongs, *Bettongia lesueur*.

The size dimorphism reported (see Chapter 2.5.1.1) suggests that females have less expendable energy resources than males, to support burrow digging, digging for food and frequent movement between burrows. This would be expected to exacerbate during lactation. However, Gibson (1999) reported that field metabolic rates did not differ between males and females during the mid-stages of their lactation, suggesting that the energy demands expended on lactation are probably compensated by other means, such as locomotory compromises. If this were the case, females would dig fewer burrows and move to and from them less frequently, as was found in the current study. Since burrows are up to 2 m deep (Finlayson 1935a, Phillipot and Smyth 1968) conservation of energy budgets would be satisfied with continued use and re-use of burrows, as was the case in the present study. Since females were breeding throughout the year, adequate food resources would have to have been available. This was the case during 1996 and 1997 at least; females also consumed a slightly greater proportion of higher quality food, particularly social insects including ants and termites during this period (Gibson 1999).

This all lends support to the idea that behavioural and locomotory compromises by females allows them to maintain smaller burrow ranges. For males, obvious considerations are the energetic costs of maintaining a greater number of burrows over a much larger area, and the

energetic cost of mate acquisition in a polygynous system i.e. maintaining a dominance hierarchy by competing with other males, to secure maximum genetic influence without loss of vigour. Larger male size and adequate available food resources appear to allow, some individuals at least, to roam across a number of smaller female home ranges and satisfy all of their social, genetic and nutritional requirements.

If the mating system (male polygyny) is determined over evolutionary time frames, then male home ranges should always be larger than females, but perhaps during times of limited food resources the home range size of each sex may become less disparate. That is, the ranges of females get larger to get more food, and those of males perhaps smaller, since they are still able to meet energetic requirements for maintenance due to the large area roamed but decrease their energy spent on reproduction. The dynamics of home range, reproductive output and the energetics of bilbies need to be investigated during times of nutritional stress to unravel these questions.

### **3.4 GENERAL SUMMARY**

The spatial organisation of burrows and knowledge of what constitutes an active burrow is critical to our effective monitoring of abundance of bilbies. As with many other species there are a number of monitoring problems in estimating absolute abundance of bilbies as opposed to monitoring them to obtain an index of abundance based on active burrow numbers. Estimates of absolute abundance may not be required or even be important in many wildlife studies (Caughley and Sinclair 1994), however in the case of dangerously low populations, such estimates can have important management implications.

The fact that bilbies dig deep burrows that are occupied for considerable amounts of time and so remain in the landscape provides a ready, indirect means of:

- a) determining where the species occurs;
- b) investigating the relationship between burrow numbers and bilby numbers; and
- c) understanding population ecology of the species including social organisation and mating systems.

The sampling limitations that endangered species such as the bilby present (fragmented, widely dispersed, low in number and difficult to trap) mean that even intensive studies such as the current study often suffer from small and incomplete data sets; this is not an uncommon situation in many field ecological studies.

The data presented in this chapter, however, provide a basis for estimating the current range and population size of bilbies using burrows as an index of bilby numbers. This will be basis of the following chapter.

## CHAPTER 4

### *CURRENT DISTRIBUTION OF THE BILBY IN QUEENSLAND BASED ON BURROWS*

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#### 4.0 INTRODUCTION

The current distribution of *M. lagotis* in Queensland is a patchy and fragmented series of sub-populations that occur within the vast, flat to gently undulating, stony and clay plains between the Diamantina River and the Simpson Desert in the State's far west. These plains are mostly treeless, with the exception of narrow wooded drainage lines that run into the major river systems of the region (see Chapter 1).

Burrows were used as an indirect method of estimating the distribution and abundance of bilbies in the study area. This was possible since burrows were readily visible from the air (Plates 4.1 and 4.2). This visibility, in combination with the data presented in Chapter three, enabled burrow density to be determined firstly from the air, and then corrected by visiting a number of randomly sampled areas on the ground, to assess activity status of burrows and finally an estimate of bilby abundance.

The area surveyed was defined within the currently known range of the species in the Diamantina region, and based on historical records; records of Queensland Parks and Wildlife surveys of the Diamantina Shire during 1981-1985 (R. Atherton *et al.* unpublished); unpublished records of R. Atherton and P. McRae (1988) during helicopter surveys; and the records of Southgate (1987). Because of the large size of the area (87 000 km<sup>2</sup>) chosen to survey, and the open, treeless nature of the landscape, aerial survey techniques were deemed a feasible and cost effective way to sample at a broad scale.



The aim of this chapter is to present estimates of bilby burrow densities at different sites in the broad study region over time. Surveys were conducted during 1994 and 1999.

## 4.1 METHODS

### 4.1.1 Aerial Survey

The survey area was stratified to sample preferred habitat and exclude areas of unsuitable habitat i.e. land zones that were not expected to be suitable such as extensive dune fields, dry salt lakes, river channels and claypans. The survey area is shown in Fig 4.1.

Visibility in the survey area was good to ground level since the entire area is grazed and vegetation cover is low, with perennial plants rarely exceeding 400 mm in height. Further, *M. lagotis* burrows to 1-2 m and in doing so excavates subsoil layers of varying colours. Excavated soil is deposited on the surface as fan-shaped mounds surrounding the burrow entrance (See Plates 4.1 and 4.2), which facilitated aerial identification of bilby burrows. Facilitation was greatest in the stony plains land systems (land system P) where the white and pink mudstone and gypsum fragments down the soil profile contrasted strongly with the reds of the ironstone gravel surface. This situation applied to a lesser extent in the clayey plains (land system F) where the soils were deeper and colour differences generally were not so obvious in the upper layers of the profile. However, bilbies usually burrowed in open areas where ground cover was low (less than 36% Southgate (1990), less than 12 % P. McRae, unpublished data) which alleviated this problem. Occasionally burrows occurred temporarily in deep cracking clay soils where there is little change in colour through the soil profile. In these cases, visibility of burrows from the air was probably reduced.

High-winged aircraft were used throughout the survey. A Cessna 172 was used for half of the 1994 survey and a Cessna 182 was used for all other surveys. Two observers seated in the rear counted burrows in a strip either side of the aircraft, while a third person seated next to the pilot recorded times and distances for survey



**Plate 4.1 Bilby burrows from the air in clay plains.**



**Plate 4.2 Bilby burrows from the air in stony plains.**



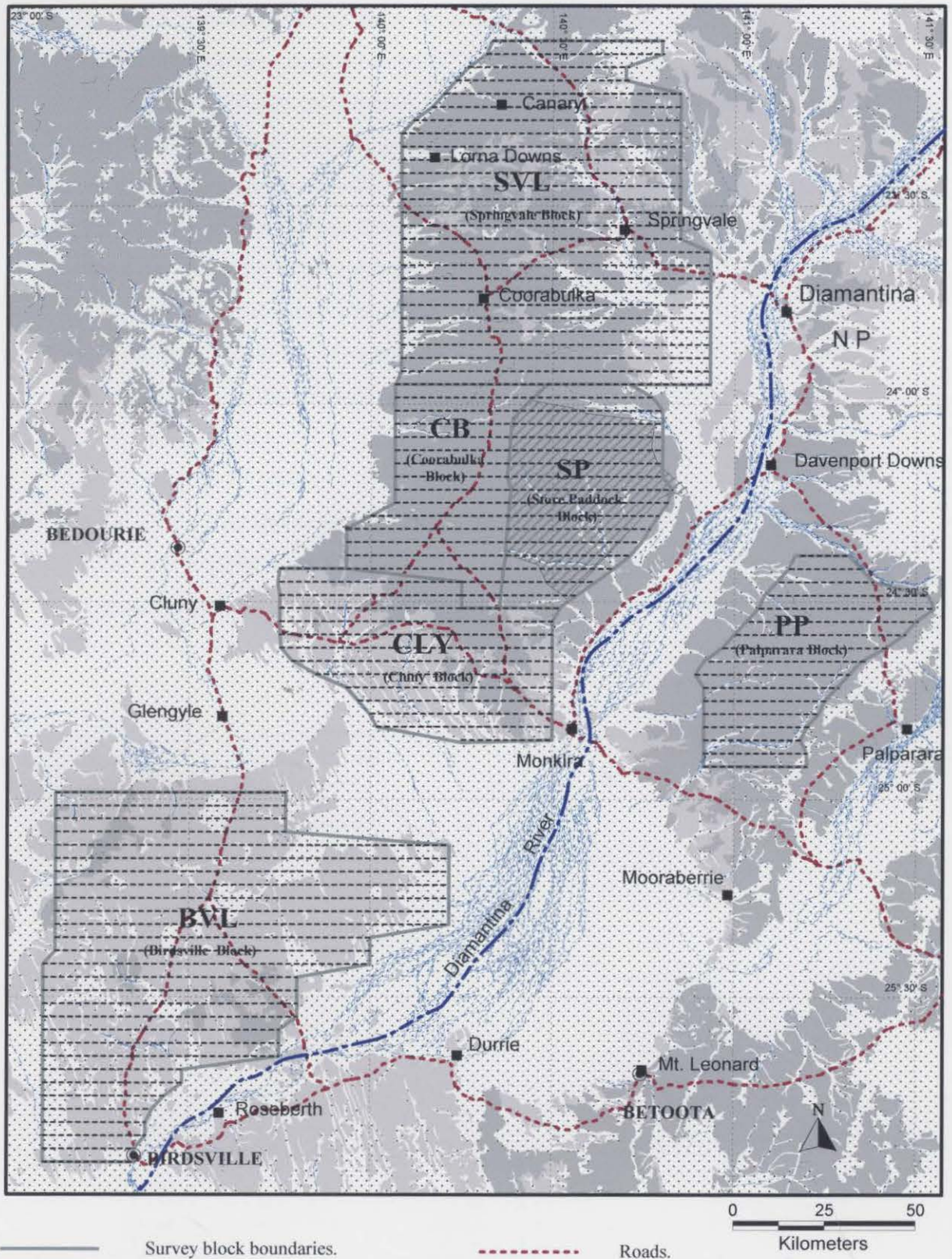
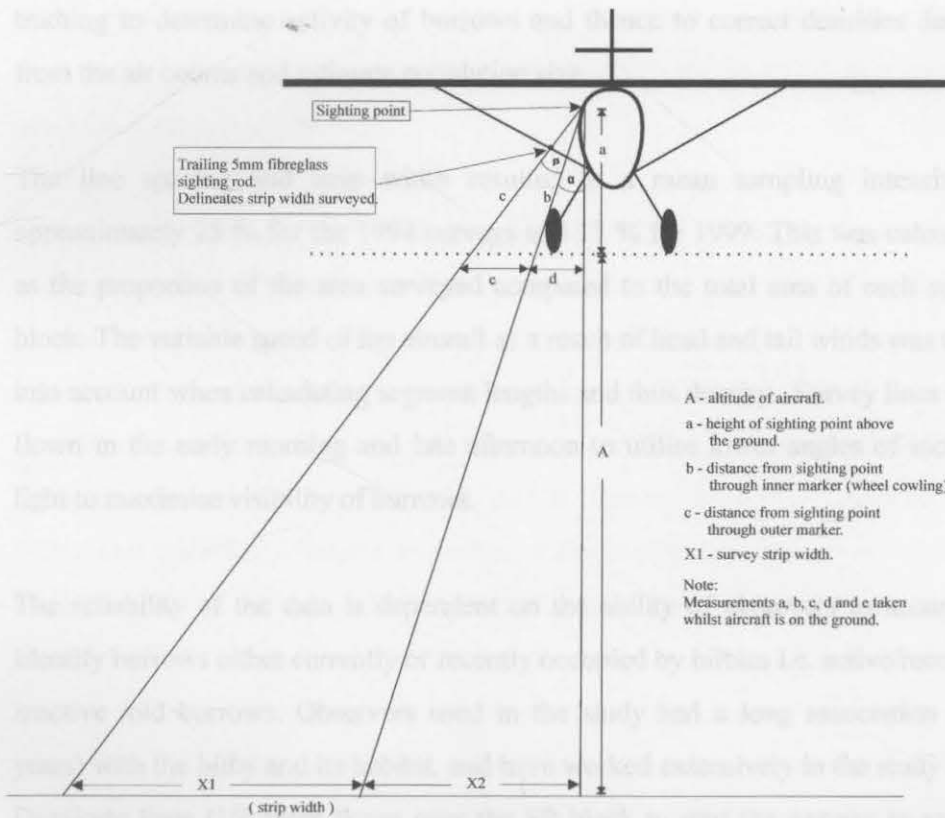


Fig. 4.1 Air survey blocks and flight lines for 1994 and 1999 burrow surveys of *Macrotis lagotis* in the channel country of Queensland.

lines and segments. Survey lines were parallel, east-west, and spaced at two minutes of latitude (approximately 3.7 km) apart. Each line was broken into segments consisting of two minutes of counting with a 30 second break to record data. SP and CB blocks are contiguous (see Fig 4.1) and survey lines for them were continuous and sampled in the same sessions. Strip width (area surveyed) was delineated by a trailing 5 mm fibreglass rod attached to each of the wing struts and taped marks on the rear window of the aircraft, a standard and widely used procedure for aerial surveys of animal populations (Caughley 1977). Strip width was calculated using trigonometry and measurements of the aircraft and sighting distances while the aircraft was on the ground (Fig 4.2), and calculated as follows:

- $\tan(\alpha) = d/a$
- $\tan(\alpha+\beta) = (e+d)/a$
- $X1 = [(A+a)\tan(\alpha+\beta)] - X2$
- $X2 = (A+a)\tan \alpha = (A+a)d/a$

therefore **Strip width : X1 = (A+a)e/a**



**Fig 4.2 Method used to determine strip width or area surveyed on the ground.**

The aircraft used for the 1999 survey was equipped with a radar altimeter, which provided greater accuracy in determination of survey height. Altitude registered by the radar altimeter and used in calculating strip width was reduced by 0.76 m due to the location of the transducer on the fuselage at the rear of the aircraft. The manufacturer of this instrument specifies an accuracy of 5%. This results in an expected variability of 6 m around the chosen survey altitude and a corresponding variation in strip width of 43 m.

Hand "click" counters were used to count burrows within the survey strip either side of the aircraft. Numbers of cattle, dingoes, kangaroos and emus were also recorded but are not reported here.

A survey height of 122 m (400 feet) was chosen following trialling of a number of altitudes to test visibility of burrows. In addition to counting individual burrows, the locations of burrow groups (larger aggregations of burrows) were recorded as stored waypoints on a global positioning system (GPS) (Magellan "Nav 1000 Pro" in the first survey and a Garmin II Plus in combination with an Appollo aircraft GPS during the second). These groups of burrows formed the basis for later ground truthing to determine activity of burrows and thence to correct densities derived from the air counts and estimate population size.

The line spacing and strip width resulted in a mean sampling intensity of approximately 25 % for the 1994 surveys and 15 % for 1999. This was calculated as the proportion of the area surveyed compared to the total area of each survey block. The variable speed of the aircraft as a result of head and tail winds was taken into account when calculating segment lengths and thus density. Survey lines were flown in the early morning and late afternoon to utilise lower angles of incident light to maximise visibility of burrows.

The reliability of the data is dependent on the ability of observers to accurately identify burrows either currently or recently occupied by bilbies i.e. active/recent or inactive /old burrows. Observers used in the study had a long association (> 5 years) with the bilby and its habitat, and have worked extensively in the study area. Duplicate lines (10) were flown over the SP block to start the surveys to refresh observer recognition of burrows from the air.



Burrows were distinguished from the diggings of other species in the following ways: (i) burrow size; (ii) amount and colour of excavated soil (bilbies can dig to 1.8 m and the soils in the area exhibit colour change with depth); (iii) bilbies usually disperse excavated soil in a single direction from the burrow leading to a fan-shaped mound clearly visible from the air (see Plates 4.1, 4.2); (iv) the entrance to, and mound of active bilby burrows is usually well scuffed, with the soil reduced to a fine powder; (v) bilby burrows have feeding "scrapes" (conical or semi-conical pits, 5-25 cm in depth) scattered in their vicinity (no other species makes these marks and they are particularly obvious in the ashy plains areas, although less so in areas of Mitchell grass or areas heavily used by livestock); (vi) other species such as dasyurids and rodents utilising burrows are much smaller (less than 150 g body mass) and their burrows are generally shallow, with only a small amount of excavated soil immediately surrounding the burrow entrance. These are barely visible from air survey height. Many also seek refuge in the deep cracks of the soil and thus produce virtually no discernible evidence of their presence. The larger varanid reptiles *Varanus spenceri*, *V. panoptes* and *V. gouldii* visit bilby burrows on a regular basis whilst foraging. However, their resident burrows are distinct from those of the bilby, with roughly scratched soil radiating out in any direction from the burrow opening.

A contour map was produced using the geographical (x, y – longitude, latitude) coordinates of the midpoint of each counting segment of all lines flown. Segment burrow density was calculated using the ratio method described by Caughley and Sinclair (1994), which accounts for survey lines of differing lengths. These point densities were used as the z-axis in conjunction with the x, y segment mid-point coordinates to enable construction of burrow density contours. Contours were constructed utilising a kriging smoothing interpolating function contained in the surface mapping system software, Surfer 7.02 (Golden Software Inc, Golden, Colorado, USA, 2000). Each contour was drawn as a continuous line following the contour interval across the surface. Contour interval selected was 2 burrows km<sup>-2</sup>. These were imported into MapInfo to enable visual and areal comparisons to be made during the two survey periods (1994 and 1999). As the sightings were based on a sampling methodology, an interpolation method was used to estimate burrow

densities for areas not sampled. The accuracy of interpolated values is dependent on the accuracy of the number of burrows counted and the spatial distribution of the sample points. Regularly spaced sample units (count segments) used in the surveys provided a grid coverage that enabled sound interpolation at the broad scale used.

#### *4.1.2 Ground Survey*

Ground surveys were conducted to assess the validity and accuracy of air burrow counts, and further, to determine the proportion of burrows active, and hence correct the air counts to arrive at a population estimate for the surveyed areas.

High and low burrow density areas were selected from those identified from the air counts and these areas were then sampled on the ground.

High-density areas were easily selected since GPS waypoints of burrow aggregations were obtained during the air surveys (see 4.1.1). In these areas, sites to survey were randomly selected from each of the survey blocks for ground assessment. In the 1994 survey 29 sites from each block were selected. Based on the experiences of this survey, the number of sites was increased to 101 in 1999, to account for the low numbers of burrow aggregations and their sparse distribution.

At each site an assessment of the areal extent of the aggregation was made and then a strip transect was designed to accommodate the majority of burrows within the group. The transect length was dependent on the extent of the aggregation. Strip width was restricted to 100 m, based on the ability of a single observer to thoroughly search the area. These strip transects were marked with star pickets and vehicle tracks.

A criss-cross traverse along the length of each transect was conducted, recording the following data: 1) number of burrows present (all species); 2) number of active bilby burrows; 3) number of inactive/old<sup>1</sup> bilby burrows; 4) presence /absence of

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<sup>1</sup> Inactive burrow: burrow with an open entrance but with no evidence of current occupation by a bilby. Old burrow: burrow obviously belonging to a bilby at some time in the past, but now containing no open entrance suitable for a bilby

bilby feed scrapes; 5) presence/absence and age of bilby faecal pellets; 6) land system of the site (see Appendix II -WARLUS land systems).

The presence of feed scrapes and pellets referred to in 4) and 5) above, was used only as an aid to the accurate identification of fresh bilby activity and the data are not reported here.

A list (not exhaustive) of plant species present at each site was compiled. The coordinates of the site centre were recorded with a GPS. Records were also kept of any active/old bilby burrows encountered during traverse between sites.

Low burrow density areas however were so sparse and clumped that vehicle transects with a 100 m strip either side of the vehicle were utilised during traverse between group sites. These were used to assess active burrows in low-density areas.

#### ***4.1.3 Population Estimates***

To establish the relationship between burrow counts from the air and bilby numbers on the ground, at a broad scale across the study area, the following issues were addressed:

1. The number of burrows used by individuals;
2. Visibility of burrows from the air; and
3. The ratio of active to old burrows as counted from the air.

The first point was addressed in Chapter 3.

The other two are correction factors related to visibility i.e. how many burrows were being missed? Are they all bilby burrows? And are the burrows currently active? Both will lead to either an 'under' or 'over' estimate of the population size. To address these issues the following procedures were used.

Observers were experienced at recognising bilby burrows. Nevertheless it is accepted that visibility/sight ability correction is essential in aerial survey work. Species as disparate as kangaroos and elephants, are both readily recognisable anatomically, but are differentially visible in differing conditions of habitat, light time of day and behaviour (see Caughley 1977, White and Garrott 1990). Similar principles could be expected to apply to bilby burrows.



To assess what these corrections might be, ground active burrow densities were calculated from surveys conducted whilst traversing the study area by vehicle, to burrow aggregations identified from the air. Burrows were counted within a 100 m strip either side of the vehicle. The discrimination between active bilby burrows and those that are not active is some times difficult from the air, irrespective of observer experience. Burrows used by individuals can at times show little sign of animal presence (see Plate 3.9 Chapter 3), which made activity status determination from 122 m in the air almost impossible. This was apparent particularly where burrows were aggregated in a small area, for example the compacted sandstone ridges in ashy plains. These areas may be only 100-200 m in length and take 3-4 seconds to fly over in air survey.

To investigate the issue of burrow status, high and low density burrow areas identified from the air were visited on the ground, where the proportion of active burrow densities could be determined. The following formula was then used to determine the overall proportion of active burrows for each survey block.

$$((TB_H * \Delta A_H) + (TB_L * \Delta A_L)) / (TB_H + TB_L) / SI$$

where :-

$TB_H$  - total air burrow count in high-density areas. (burrow density  $> 4\text{km}^{-2}$ )

$TB_L$  - total air burrow count in low-density areas. (burrow density  $< 4\text{km}^{-2}$ )

$\Delta A_H$  - proportion of burrows active in high density areas; derived from ground counts.

$\Delta A_L$  - proportion of burrows active in low density areas; derived from ground counts.

$SI$  - block sampling intensity.

The value obtained was then used to calculate total active burrow estimates for each of the survey blocks. The resulting burrow numbers were divided by estimates of numbers of burrows used by individuals (see chapter Table 3.2 ) to arrive at a total population estimate.

Burrow densities were compared between the six blocks and two time periods using 2-factor analysis of variance, followed by post-hoc Tukey tests to determine where significant difference occurred. Data were all log transformed to satisfy statistical requirements of normality.

## 4.2 RESULTS AND DISCUSSION

### 4.2.1 Air Survey

A total of 6586 km (1994) and 6605 km (1999) of survey lines were flown during the two survey periods. A summary of results obtained is shown in Table 4.1 These data consist of the raw, uncorrected counts of burrow numbers and thus indicate a relative index of bilby numbers in each of the survey blocks.

A total of 770 (1994) and 880 (1999) point burrow densities were calculated from the two surveys. The difference between the numbers of point densities for each survey was a consequence of difference in aircraft types and variability in speed that resulted in longer or shorter counting segments for particular survey flight lines.

Interpolated GIS burrow density data are shown in Figs 4.3 and 4.4. These show the distribution of burrow densities throughout each survey block. Calculated point densities and interpolated densities have been colour coded throughout the range of densities from zero to the highest density recorded. In addition contour lines with a contour interval of two burrows km<sup>-2</sup> have been added for burrow densities > 2 burrows km<sup>-2</sup>. This was done to highlight areas that could be considered to be either on the fringes of, or part of an area likely to contain a resident population of bilbies. Burrow densities for the survey periods were lower in all blocks in 1999 with the exception of CB. SP had the highest burrow density in both survey periods.

PP had a significantly lower burrow density in 1999 (ANOVA;  $F_{1,29} = 9.805$ ,  $p = 0.004$ ), as did BVL (ANOVA;  $F_{1,44} = 16.117$ ,  $p = 0.000$ ).

The clayey plains blocks of CB, SP and PP (see Fig 4.1) had higher burrow densities than the main stony plains BVL block (Tukey HSD;  $p = 0.000$ ). The CLY and SVL block densities were low in both survey periods.

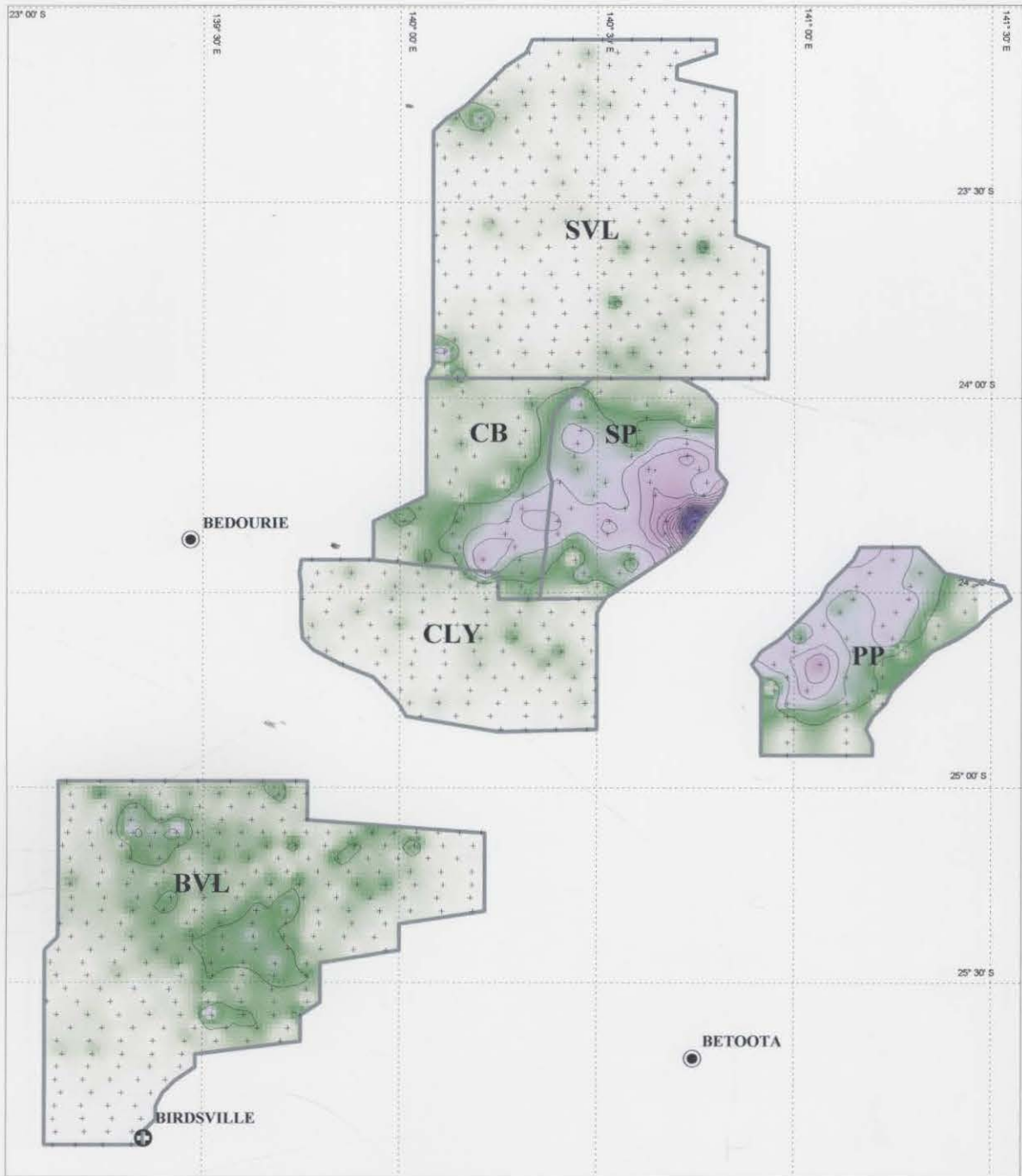
**Table 4.1 Summary of air survey results with mean block burrow densities for the two survey periods.**

Year	Block	Number of lines	Sample intensity (%)	Strip width (km)	Line length surveyed (km)	Total burrow count	Density $\pm$ se (km <sup>-2</sup> )	Probability*
	SP	18	33.6	1.32	603	3301	4.15 $\pm$ 0.44	
1	CB	18	31.2	1.32	500	1177	1.78 $\pm$ 0.25	
9	PP	17	33.0	1.32	552	2161	2.97 $\pm$ 0.29	
9	SVL	27	15.1	0.70	1587	246	0.22 $\pm$ 0.04	
4	BVL	29	19.2	0.88	1630	1312	0.91 $\pm$ 0.07	
	CLY	14	19.4	0.88	648	270	0.47 $\pm$ 0.10	
	SP	18	13.8	0.70	521	1025	3.14 $\pm$ 0.57	ns
1	CB	18	14.4	0.70	468	705	2.31 $\pm$ 0.57	ns
9	PP	17	15.5	0.70	491	255	0.75 $\pm$ 0.11	*
9	SVL	27	15.1	0.70	1598	58	0.05 $\pm$ 0.02	ns
9	BVL	29	15.1	0.70	1631	257	0.23 $\pm$ 0.04	*
	CLY	14	14.8	0.70	629	78	0.18 $\pm$ 0.10	ns

SP: store paddock, CB : Coorabulka, PP : Palparara, SVL : Springvale, BVL : Birdsville, CLY : Cluny.

\* probability refers to results from ANOVA and post-hoc comparisons for blocks between years.

These data suggest the ashy clay plains support greater densities of bilbies than do the stony plains. This could be attributed to a number of factors; land management, differential predation rates or habit preference by bilbies. Food resources were found not to be energetically limiting for bilbies in the ashy plains of Astrebla Downs National Park (Gibson 2001), but no studies of food availability in the stony plains areas have been undertaken. Plant responses in these areas where the soils are shallower, appear to be quite different to those in the deep cracking clay soils of the SP, PP and CB blocks. Ephemeral plant response is rapid in both areas, though less rainfall is required to promote ephemeral response in the stony areas.

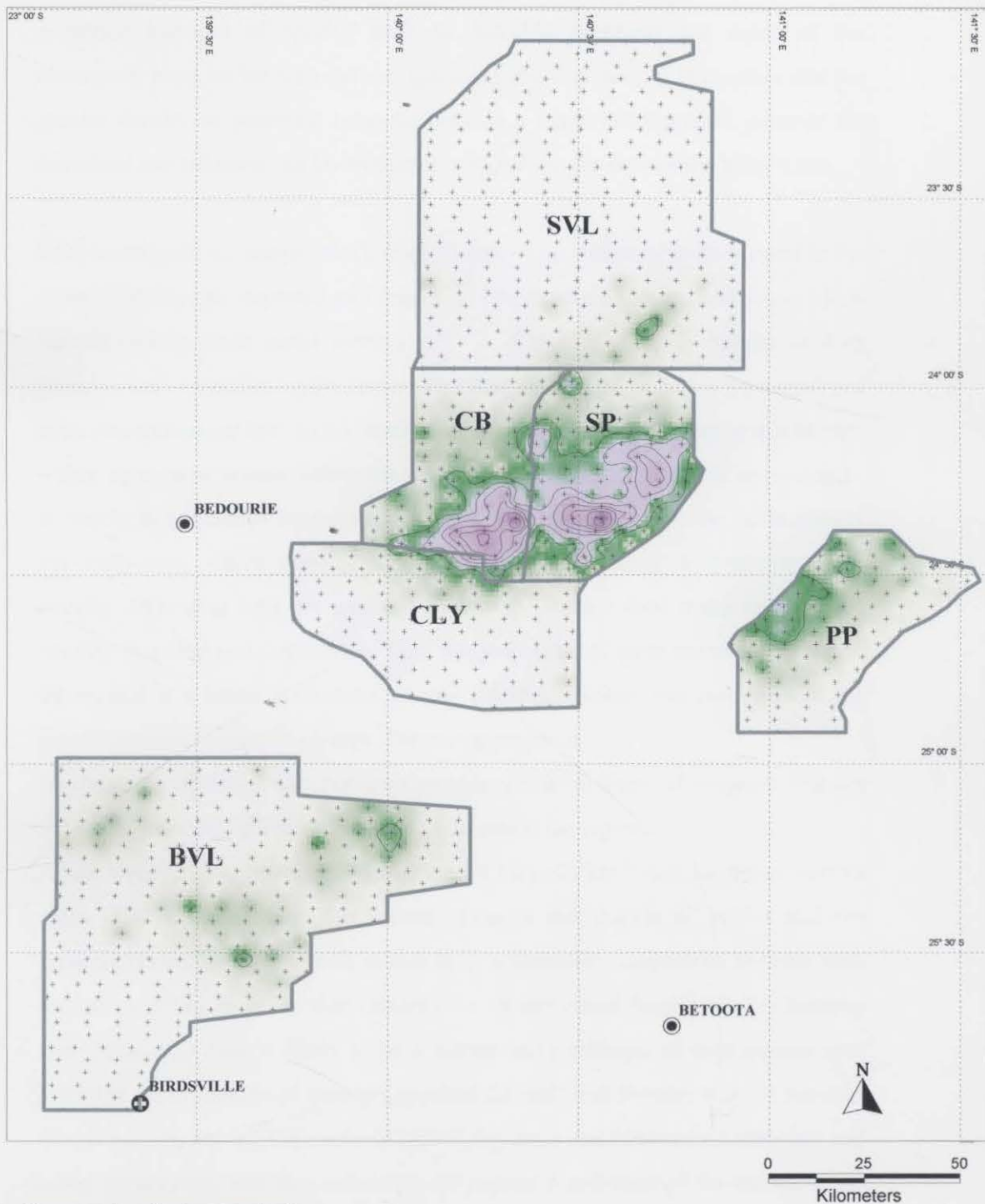


**Burrow density (per sq. km.)**

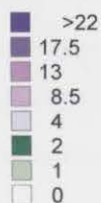


- \* contour interval - 2 burrows / km<sup>2</sup>
- \* minimum countour - 2 burrows / km<sup>2</sup>
- + point burrow densities obtained from air surveys

**Fig 4.3. Burrow densities of *Macrotis lagotis* determined from aerial survey, 1994.**



Burrow density ( per sq km)



\* contour interval - 2 burrows /km<sup>2</sup>

\* minimum contour - 2 burrows / km<sup>2</sup>

+ point burrow densities obtained from air surveys.

Fig 4.4 Burrow densities of *Macrotis lagotis* determined from aerial survey, 1999.

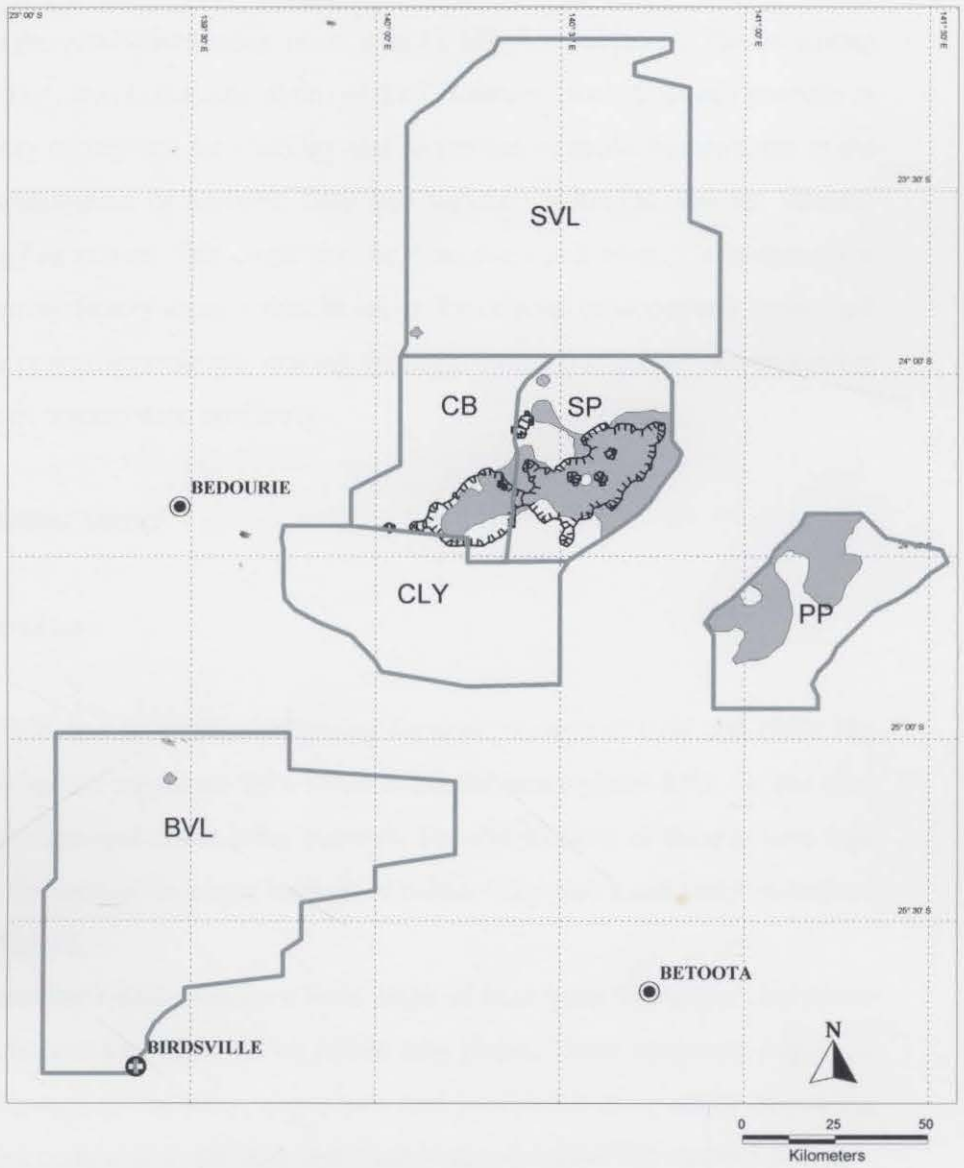
The clay areas however produce a lasting response to substantial rainfall, and the perennial tussocks of species such as *Astrebla pectinata* and many of the chenopods hang on for long periods (personal observations). It is possible that the greater density of perennial tussocks provide a longer lasting food resource for terrestrial and subterranean invertebrates, which form the bulk of the bilby's diet.

At a broad scale i.e. survey block level, burrow densities need to be viewed in the context of the data reported in Chapter 3. For example the greatest mean block burrow density from aerial surveys was SP (1994) that had a density of 4.15 burrows km<sup>-2</sup>. Considering the burrow use data from Chapter 3, this represents not quite one animal per km<sup>2</sup>. In this study bilbies did not generally occur at this density – they aggregated in areas where the substrate was suitable for burrow construction, in proximity to suitable food resources (personal observations). In the landscapes of the study area, where there is a patchy mosaic of geology determining where suitable burrowing soils are located adjacent to suitable food resources, this has resulted in a clumped distribution. The clumped nature of these resources cannot be interpreted at a broad scale since overall (block) densities will misrepresent the actual densities within the clumps (burrow aggregations).

Overall block densities did, however provide a relative index of temporal changes in burrow numbers and thus population size across the region.

Areas surveyed that contained greater than 4 burrows km<sup>-2</sup> were identified as core areas. This was based on the known clumped distribution of bilbies and the unlikely occurrence of animals establishing sustainable populations in areas with burrow densities less than that required for an individual female i.e. 3.6 burrows (see Table 3.2) This is likely to be a conservative estimate of core burrow area since the mean number of burrows required for male and females was 5.4 burrows (Table 3.2). However, it is useful in identifying areas that bilbies were selecting and using periodically, and thus estimating the current distribution of the species in the study area.

Core areas identified for both survey periods are shown in Fig 4.5 and were: 2103 km<sup>2</sup>, and 1133 km<sup>2</sup> in 1994 and 1999 respectively. This represents almost a 50% reduction in area over the 5-year period.



**Fig 4.5 Change in core areas of burrow density : 1994 to 1999.**

Of the core area identified in 1999, 724 km<sup>2</sup> was in the SP block, representing 65% of the total area surveyed in the block. All of this area was contained within the bounds of Astrebla Downs National Park, which was gazetted in 1995. This lends support to the park's declaration as an area for bilby conservation. The remaining 35%, 409 km<sup>2</sup>, was in the ashy plains of the CB survey block. It wasn't possible to correct every survey line for visibility and proportion of active burrows due to the clumped distribution of burrows, time and logistic constraints, and the inherent problems of air counts. This could only be done at a block level. The construction of core burrow density areas is thus based on the original (uncorrected) counts and is likely to be an over-estimate, making the range contraction greater and presenting more serious conservation problems.

#### **4.2.2 Ground Survey**

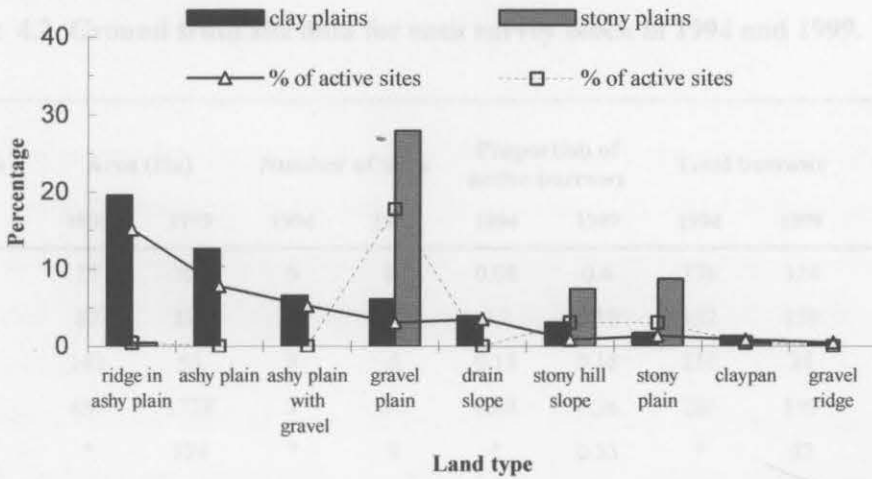
##### *4.2.2.1 Land type*

A total of 308 sites was visited following the aerial surveys of 1994 and 1999. The clay plains habitat contained 55% of sites and the stony plains 45%. Of the sites visited 232 contained active bilby burrows. The distributions of these in land type categories for each of the major habitats of bilbies (clay plains and stony plains) are shown in Fig 4.6.

It is apparent the bilbies occupy a wide range of land types within the clay plains with a preference for ridges (15%) within ashy plains. These sandstone ridges are scattered throughout the ashy, clay plains and provided a more stable burrowing environment compared to the deep self-mulching soils of the surrounding plains.

In the stony plains habitat, 18% of the active sites occurred in the gravel plains. Active sites in stony plains and hill slopes accounted for only 6% of all active sites. The gravel plains consisted of much smaller stones, usually less than 10 mm in size, compared to the stony plains that contained gibber sized rocks that could be between 20-100 mm in diameter. These areas tended to support less vegetation and probably provide fewer food resources for bilbies (personal observations).





**Fig 4.6. Ground truth site habitat categories (clayey plains and stony plains) showing percentage of each land type, and percentage of total active sites within each grouping.**

Results obtained from the ground surveys are summarised in Table 4.2.

The most significant change over the two periods is the change in active burrow density in the SVL block, which results from a very small area containing a high proportion of active burrows. In context of the area of the entire SVL survey block (7 378 km<sup>2</sup>) and overall burrow density of 0.05 km<sup>-2</sup> (Table 4.1), this is of little consequence.

Active burrow densities for the other blocks didn't change as dramatically although the CB density was considerably lower in 1999. These changes could be a function of the smaller sample sizes for 1994, or an unknown factor in land management practises or predation rates. SP block densities were high in both surveys.

The proportion of active burrows from ground surveys used to calculate individual block estimates of the proportion of active burrows (see formula in 4.1.3.) is shown in Table 4.3. These are the results of visiting high-density areas of burrows recorded during air surveys and visiting similar areas on the ground to record active burrow density on the ground. Derived correction factors were used to adjust the aerial burrow counts to estimate population size in each of the survey blocks.

**Table 4.2 Ground truth site data for each survey block in 1994 and 1999.**

Block	Area (Ha)		Number of Sites		Proportion of active burrows		Total burrows		Active burrow density km <sup>-2</sup>	
	1994	1999	1994	1999	1994	1999	1994	1999	1994	1999
SP	27	225	6	32	0.08	0.4	176	324	51.9	58.2
CB	87	316	8	19	0.2	0.18	152	159	34.5	9.2
PP	143	56	8	6	0.13	0.18	216	34	19.6	10.8
BVL	457	1778	7	35	0.08	0.26	286	199	5	2.9
CLY	*	174	*	9	*	0.33	*	92	*	17.3
SVL	1843	75	12	7	0.09	0.46	166	50	0.8	30.9

\* no data for Cluny block 1994.

**Table 4.3 Ground truth active burrow proportions in high and low density areas, and derived correction factors for each survey block in 1994 and 1999.**

Block	1994	1999	1999		1999		1994		1999		1994	1999
	Sample Intensity	Sample Intensity	Prop. Active	Prop. Active	Prop. Active	Prop. Active	Air count	Air count	Air count	Air count	Correct factor	Correct factor
			H	L	H	L	H	L	H	L		
SP	0.34	0.14	0.15	0.03	0.58	0.42	2556	745	786	239	0.12	0.54
CB	0.31	0.14	0.41	0.19	0.22	0.03	323	854	519	185	0.25	0.17
PP	0.33	0.15	0.19	0.03	0	0.18	1448	713	0	255	0.14	0.18
BVL	0.19	0.15	0	0.05	0	0.57	0	1312	0	257	0.05	0.57
SVL	0.15	0.15	0	0.11	0	0.81	0	246	0	58	0.11	0.81
CLY	0.19	0.15	0	0.05	0	0.53	0	270	0	78	0.05	0.53

H = high density, L = low density

#### *4.2.2.2 Visibility correction*

Ground surveys were not initially undertaken to make a visibility assessment but rather to compare burrow status i.e. active versus old from the ground and air, at a block scale. Comparisons of the burrow density along individual flight segments with those obtained on the ground, could only be made where ground surveys coincided with flight lines. And there were insufficient data to enable such comparisons.

It would have been better to make comparisons of individual segment counts from the air with ground counts over the same areas. Future surveys will attempt to refine methods by using more accurate differential GPS tracking logs in the aircraft that will enable the exact flight paths of lines flown to be plotted. This would allow burrow density estimates from both methods to be compared.

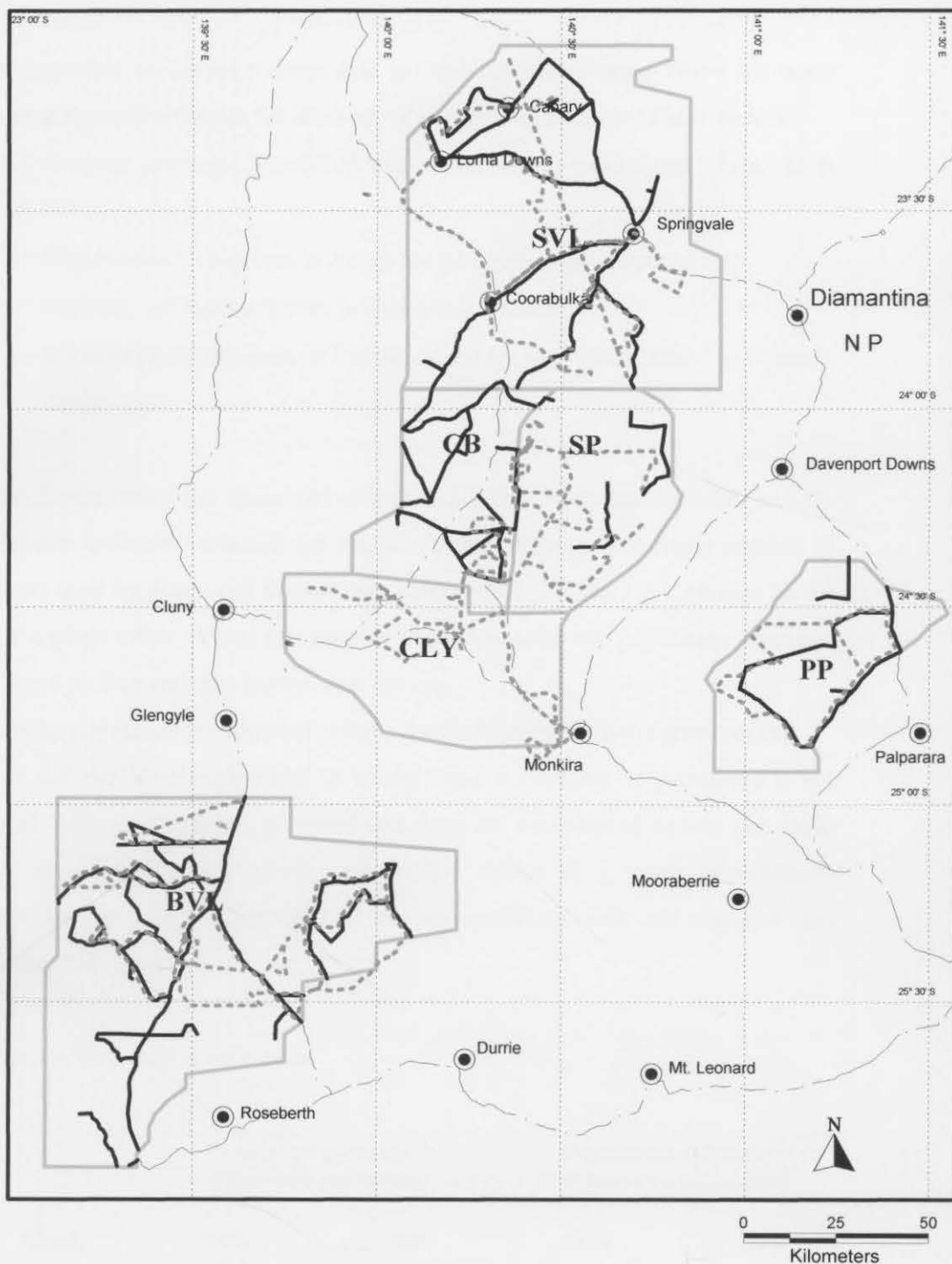
To overcome this shortcoming, burrow densities were calculated from extensive traversing of all blocks during ground surveys: 1502 km in 1994, 1837 km in 1999 (see Fig 4.7). Active burrow density was calculated based on records of active burrows recorded in a 100 m strip each side of the vehicle during most of these traverses.

These were then apportioned to one of either the high or low burrow density categories derived from the air burrow densities contours, compared to burrow densities from the air, and a visibility correction factor obtained.

Mean block visibility corrections calculated were 0.75 for the clayey plains blocks of CB, SP, PP, and SVL; and 1.7 for the stony plains blocks of BVL and CLY. These data indicate that aerial surveys tended to slightly overestimate burrow densities in the areas of high density and conversely underestimate densities in the low-density areas.

#### *4.2.2.3 Population Estimates*

Using the correction factor for active burrows, visibility corrections and the number of burrows used by bilbies, estimates of population size in each block were made for the two survey periods. These are listed in Table 4.4.



- Ground traverse route 1994: length - 1 502 km
- - - Ground traverse route 1999: length - 1 837 km
- Aerial survey block boundaries.
- - - Roads

*Note: Ground traverse for 1999 has been moved approximately 1 km north and west on the map, to avoid any overlap with the 1994 route.*

**Fig. 4.7 Location of ground traverses 1994 and 1999.**

It is important to consider these data as basic estimates only. There are many factors that could influence the accuracy of population estimates. These include:

- Inherent problems associated with aerial survey techniques alluded to in 4.1.1;
- Experience of observers in recognising bilby burrows from the air;
- Visibility correction factors in different landscapes;
- Knowledge of numbers of burrows used by individual bilbies in different landscapes;

These factors have been addressed as best as possible in the present study and the population estimates obtained are realistic in this context. The mean number of burrows used by males and females was recorded as 5.4 (see 3.2.3, chapter 3). To cover a range either side of this number of burrows, the two population estimates are based on four and nine burrows per animal.

The bilby population is estimated to have doubled during the two survey periods. Given the reproductive potential of bilbies, such a doubling of population is not inconceivable over a five-year period and there are a number of factors that could have contributed to it: Greater reproductive output as a result of enhanced conditions primarily rainfall; and /or reduced predation rates and changed land management practices.

**Table 4.4 Population estimates**

<b>Block</b>	<b>Population estimate 1: 4 burrows per animal</b>		<b>Population estimate 2: 9 burrows per animal</b>	
	<b>1994</b>	<b>1999</b>	<b>1994</b>	<b>1999</b>
<b>SP</b>	226	756	101	336
<b>CB</b>	177	155	79	69
<b>PP</b>	169	56	75	25
<b>SVL</b>	34	58	15	26
<b>BVL</b>	144	412	64	183
<b>CLY</b>	30	119	13	53
<b>total</b>	<b>780</b>	<b>1556</b>	<b>347</b>	<b>692</b>

Of concern is that whilst the population appeared to double over the 5 year period, a large contraction in what was defined as core burrow density area occurred. This contraction resulted in 65% of core burrow areas being located within Astrebla Downs National Park by 1999. Of particular concern is the status of the bilby population in the PP block, which is geographically isolated from the National Park by the major timbered network of channels that constitute the Diamantina River. It is possible this population, the most easterly occurring in Queensland, could become locally extinct if the declines observed in this study are real, and the threatening processes continue. Air surveys are due to be conducted again in 2005 and should be able to identify any changes in distribution.

#### **4.3 SUMMARY AND GENERAL DISCUSSION**

##### **1. Air survey techniques**

The system of aerial survey is inherently 'sloppy', given the expected accuracy within manufacturers' specifications of altitude instruments, coupled with the dynamic behaviour of aircraft under varying conditions of pressure. Accuracy/precision is also dependent on individual pilot vigilance. Changes in survey height, from unexpected changes in aircraft altitude as a result of changes in air pressure and wind gusts, can dramatically change strip width surveyed. Moreover, movement of the observing position (height of observer and/or changes in head position) within the aircraft as a result of simple head movements, can change strip widths, albeit minimally. For example, a change in the observing position (i.e. height of observers' eyes above the ground) of 1 cm results in a calculated strip width change of 4.5 m. Similarly, a change in aircraft altitude of only 10 m (insignificant in an aeronautical context) results in a strip width change of 72 m. This inherent variability notwithstanding, the method is the best available to cover large areas in a cost effective manner. However, users should be aware of the inherent problems referred to, attempt to address them as best as possible and not draw conclusions that assume great accuracy.

In the 1999 survey a radar altimeter was fitted to the aircraft, which decreased the variability in altitude flown on the survey lines. The 1994 survey depended on the experience of the pilot at maintaining altitude. I had full confidence in the pilot's vigilance in this regard, and expect relative densities should not be too dissimilar.

## 2. Population changes

In the sampled populations from this study the sex ratio of adults was found to be close to parity (2.3.2. Chapter 2). The data presented in Chapter 3 suggest that males are using on average twice as many burrows as females and over almost five times the area. To arrive at a population estimate or at least an index, one must apportion burrow numbers roughly in the ratio 2:1 (male to female). If females are using on average four burrows per week, and males seven, then 11 active burrows equals either two animals- a male and a female; or 2-3 females, or one male. Given a better understanding of burrow use coupled with long term monitoring, it should be possible to determine the nature (single sex or not) of small burrow aggregations simply because these should not persist in the long term unless some behavioural attribute such as bachelor or spinster groupings are shown to exist.

The core areas of bilby persistence were estimated based on burrow densities of greater than 4 km<sup>-2</sup>. These areas were calculated on a combination of point densities determined from air surveys and interpolated densities based on these data. This value of 4 km<sup>-2</sup> is still a very low density in terms of burrows used by individual animals, particularly when it is recognised that bilbies aggregated in defined areas such as sandstone ridges and along drainage lines. This suggests that population sizes could be even smaller than those estimated here.

## Summary

The technique used here, i.e. air survey followed by ground truthing of randomly selected subsets of the area, is repeatable and cost effective over broad areas. However, due to the persistence of bilby burrows in this landscape, over considerable periods of time, the sensitivity of the technique in detecting changes in the activity of burrows is heavily reliant on ground truthing.

The surveys of burrows have enabled an estimation of the current distribution of the bilby in the study area. Further, critical areas, where concentrations of bilbies are likely to be greatest were determined and represent a spatial estimation of the currently known distribution of the species in Queensland.

In the Chapter to follow, the results of the current Chapter are placed in context with the known historical distribution of the bilby in Queensland, and reasons for the changes in range are discussed.



## CHAPTER 5

### *HISTORICAL DECLINES IN THE DISTRIBUTION OF THE BILBY IN QUEENSLAND*

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#### 5.0 INTRODUCTION

This chapter puts the current estimated distribution determined in the previous Chapter, in an historical context. It documents and reviews the scientific literature, museum records and historical accounts of bilby sightings in Queensland up until 1985. Accounts have also been compiled from a series of personal communications provided to the author in an incidental manner over the past 15 years. Reference to shire history books and government reports provided further brief reference sources to the existence of the species, particularly in the southern part of its range.

The extensive surveys of R. Southgate throughout Australia in the 1980s provided the most comprehensive assimilation of the current and former distribution of the bilby in mainland Australia at the time (see Southgate 1987, 1990a,b), and provided an invaluable basis for the chapter.

The bilby has suffered a severe range contraction across mainland Australia since it was first described by Reid in 1837 (Gray 1841, Krefft 1862, Thomas 1888, Gould 1863, Jones 1923, Finlayson 1961, Phillpot and Smythe 1967, Southgate 1990b, Johnson 1995).

Early declines across the continent occurred from the south, resulting in extinction of the species in NSW by 1912 (Troughton 1932) and in SA by the early 1930s (Kemper 1990). No definite records exist for Victoria, but there is confusion over the provenance and locality of two museum specimens, and earlier comments by Krefft in 1866 have at times resulted in the species being reported to occur in Victoria (Scarlett 1969, Menkhorst and Seebeck 1990). Southgate (1990b) also reported on this confusion but considered it not

unreasonable to accept that it existed in the northern mallee areas of the state at the turn of the century. The species is still extant in WA; however, it has declined dramatically from the south west, with Friend (1990) reporting rapid extinction in the southwest corner of the state after about 1935. Southgate (1990b) reported similar declines from the South Australian border to Alice Springs and in the northern pastoral country of the Northern Territory. In Queensland the species was once widespread west of the Great Dividing Range, through central Queensland to the New South Wales border. It has declined dramatically from the south and east, resulting in an isolated and fragmented extant population in the far south west of the State (Gordon et al.1990).

By around 1970, all existing mainland populations occurred north of approximately latitude 29° South. Apart from South Australia and New South Wales, where the species is now extinct, the population declines have been most dramatic in Queensland.

## **5.1 HISTORICAL ACCOUNTS OF THE BILBY IN WESTERN QUEENSLAND**

There are few references in the scientific literature to the distribution and abundance of the species in Queensland, particularly prior to the 1970s. A majority of these refer to the species in the western part of its range in the State. Literature records in this period are restricted to a few scientific accounts (see Wood Jones 1923; Finlayson 1961; Phillipot and Smythe 1967) and anecdotal reference to bilbies in lesser known natural history books and State Government reports and journals (see Coghlan 1895; Duncan Kemp 1935, 1952; Dent 1972). Range contraction occurred from the south at a continental level (Southgate 1990a,b), but in Queensland, where the species is at the northern limits of its range in the State, there also has been a major contraction from east to west. Unfortunately, the few early scientific accounts of the species are from far western areas, even though European settlement proceeded from the east. Pastoral expansion in the east commenced in the early 1850s. The pastoral spread radiated west from the Darling Downs, and by 1870 all of Queensland had been

occupied to varying degrees. By 1914 the boundary of European settlement was similar to the present (Barnard 1969).

The dearth of fauna accounts associated with the pastoral spread west from Brisbane may be related to the nature of those involved i.e. pastoralists with aims of land acquisition and pastoral improvement riding paramount in their minds. Western Queensland was first settled in the late 1860s. However, the area remained of frontier interest to many, judging by the amount of visitation from explorers traversing the inland occurring after Sturt's first visit in 1845 - (Burke and Wills, Mitchell, Landsborough, Leichhardt and others). Perhaps the nature of these 'adventurers', not totally driven by pastoral expansion, resulted in greater observation and subsequent recording of their accounts of elements of the landscape and its biota. Even so, the literature records (scientific and historical) are still scant and without great detail.

Records of *M. lagotis* from this early period are listed below:

1. Spencer (1896) refers to the bilby as "*not uncommon...*" on his voyages through central Australia from Adelaide to Alice Springs in the 1890s;
2. "*bilbies are fairly numerous*" in the "Glenormiston" area (Coghlan 1895). This is part of the present study area;
3. In the "Springvale" and Boulia areas of the present study area:  
"*Even in those days (1910) the bilby was on the verge of extinction*", "*but I have only twice seen them alive*". "*The last time I saw one alive was in October of that year (1910)*" (Dent 1972);
4. "*Another Boulia resident. recalls that many years ago he saw a bilby kept in a cage at Dajarra, 96 miles away.*" (Dent 1972). This is approximately 200 km north of the present study area;
5. A South Australian Museum expedition found the species to be in low numbers in the Mungeranie area in South Australia as early as 1916. An old skull was found and some tracks observed. Aboriginal knowledge of the species was also acknowledged (Waite 1917);
6. A living animal was transported from "Bulgroo Station" via Adavale, to Heber Longman, then Director of the Queensland Museum in October 1921 by J. Horsington (Longman 1922).

7. “*there is certainly no part of this state where the bilby is not a rapidly disappearing animal*”. Wood Jones (1924) referring to South Australia;
8. “*.. in parts of the country thousands of acres of loamy mulga flats have been closely harrowed by its scratchings in search of beetle larvae, which occur there*”. (Finlayson 1936) also with reference to South Australia.
9. An old Aboriginal man reported to C. Dickman that bilbies used to occur on the Mulligan River (approximately 150km west of the present study area) at least until the 1930s. (C. Dickman pers. comm. 2004);
10. Three living individuals and a skin (all males) were collected by I. Filmer from the Queensland Museum between 1957 and 1959 in the vicinity of Birdsville (Mack 1961).
11. Philpott and Smythe (1967) reported observations of animals that they considered to be *M. lagotis* from west of “Glengyle” homestead, in the present study area, between 1965 and 1967. They also reported that the species was only commonly encountered during their travels in the Warburton area of Western Australia.
12. Tom Tully recounted often seeing bilbies on the road between “Springvale” and Boulia near “Coorabulka” No2 bore in the 1960s and 1970s. Tom was manager of “Springvale” for nearly 20 years. He also worked for many years on “Cluny”, in the present study area, but doesn’t ever recall seeing bilbies there (T. Tully pers. comm. 1993);
13. Gordon Robinson, a long term property owner in the area, similarly reported large numbers of bilbies on “Springvale”, “Canary” and “Lorna Downs” in the 1960s and 1970s – often seeing six or seven a night whilst spotlighting and shooting kangaroos (G.Robinson pers. comm. 1993);
14. Arthur Churches, who spent most of his life on “Mooraberrie”, immediately south east of the present study area, last saw bilbies on the place in the early 1970s (A. Churches pers. comm.1991);
15. A bilby was caught and kept as a pet at “Lorna Downs” (within the present study area) in 1971 (E. Ogilvie pers. comm. 1988);
16. Herb Rabig, a long term property owner in the far west recalled that he had never seen bilbies on “Cuddappan”, approximately 150 km south east of the present study area. (H. Rabig pers.comm. 1991).

It appears that the bilby was widespread in the study area from the 1930s until the 1970s and began declining perhaps in the 1920s and 1930s. This agrees with that reported by Wood Jones (1924) in central Australia.

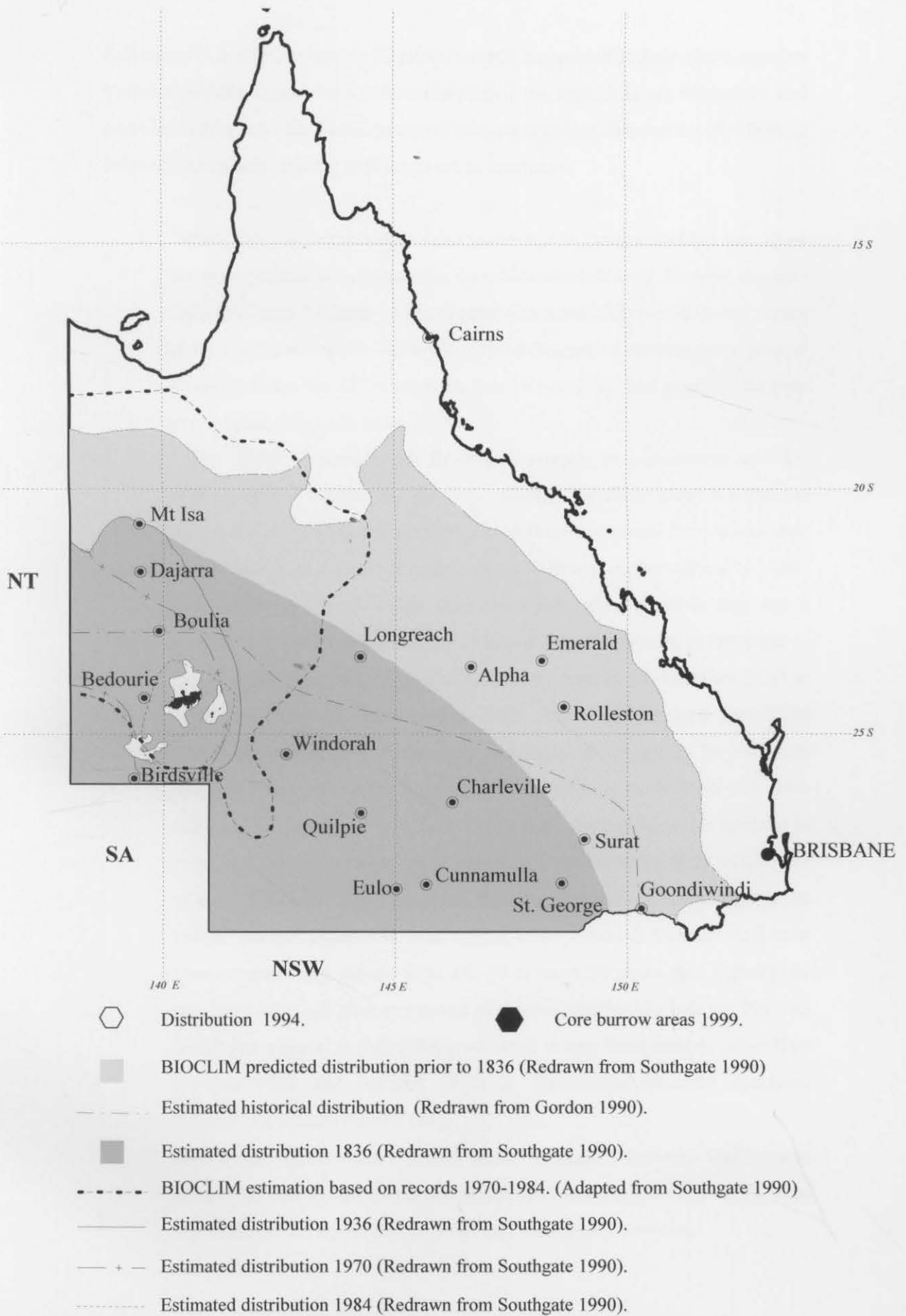
The depauperate nature of literature records is reflected in the specimen records from museums. These number 10, and are recorded from only four localities in Queensland up until 1958. Of these, eight specimens are from the Birdsville/Diamantina region (between 1931 and 1958); one from between Quilpie and Windorah (1922); and a solitary eastern specimen from Surat (1912) in the Maranoa region of the western Darling Downs.

The current distribution of the species and the historical accounts obtained during this study are placed in context with the distribution estimates of Southgate (1990) and Gordon *et al.* (1990), in Fig.5.1.

Southgate (1990b) used bilby records and climate data, to estimate the distribution of bilbies prior to European settlement (all bilby records 1836-1984), and at 1984 (bilby records 1970-1984), using BIOCLIM analysis. He further estimated the decline in distribution of the species based on literature records, museum and survey records for a number of historical dates: 1836; 1936; 1970 and 1984. Gordon *et al.* (1990) also provided an historical estimate of the distribution of the bilby in Queensland based on survey records, museum specimens, literature accounts and reliable reports.

## **5.2 HISTORICAL DISTRIBUTION IN THE SOUTH EAST OF THE STATE**

There has also been a paucity of records of *M. lagotis* in the scientific literature that relate to the former range of the species, particularly in the eastern and central areas of Queensland. The most easterly record of the species in Queensland is recorded from a museum specimen from Surat in 1912. Abbott (2001) provided a fine example of what talking to long-term residents and local knowledge could do to refine and improve our knowledge of the past distribution of a species. This can be invaluable in interpreting the spatial and temporal declines in areas.



**Fig 5.1 Map of Queensland showing former distribution (until 1985) of *Macrotis lagotis* in Queensland.**

Following is a brief review of literature records assembled to help piece together historical distribution in the southeastern part of the state. It is not exhaustive and provides only a basis for further research into the previous distribution of bilbies in eastern Queensland utilising a different set of resources:

1. *“When I was a lad wombats were numerous in Queensland but now there are none; bilbies were numerous from Goondiwindi to St. George, but now there are none.”* (Gunn 1937). Donald Gunn was born in 1856 and writes about the Stanthorpe – Warwick - Pikedale area i.e. bilbies were present around perhaps the 1870s when he was 14 years old, and gone by the time of publishing the book in 1937.
2. *“The “Bilby” resembles the Silver-grey possum in appearance, with big night eyes, but it hops like the ‘roo’ family. The Bilby lives in a burrow during the day and is seldom seen. This fellow has always been scarce and, only if caught in a beam at night is it seen. So it is rather difficult to judge their numbers. The fact that they are rarely seen, suggests they are a rarity.”* (V.E. Wehl in Armstrong 1970). Wehl was referring to the fauna of the Warroo Shire centred on Surat. He was born at Mt Gambier (SA) in 1865 and came to Surat around 1882. Armstrong reported that Wehl contributed the articles on the flora and fauna of the district “*a few years ago*” i.e. a few years prior to 1970. This would have made Wehl 105 years old in 1970 – if still alive. Given Armstrong’s language, one is tempted to postulate, ‘*a few years ago*’ to be less than 10 years. If so, Wehl, at the time of writing, would have been in his 90s. How current his knowledge of the species present in the area was, cannot be ascertained. He may well have been remembering bilbies from 30, 40 or even 50 years ago. Equally, he may have been still alert and aware of species distributions into his 90s. The best I can suggest is that bilbies occurred in the Surat area at some time between 1882 and perhaps 1960. A Queensland Museum specimen certainly confirms a date of 1912.
3. Don Peglar (pers. comm. 1990) from “Trinidad” between Quilpie and Windorah, related that his parents remember bilbies in the “Thylungra” area in the 1950s, but added that they weren’t particularly common.

4. Charleville resident Darryl Duff (pers. comm. 2002) related that his grandfather took him to a site on “Regleigh” near “Thylungra” (between Quilpie and Windorah) in the 1970s to show him bilby burrows on a stony rise off sandy country.
5. There is indirect evidence of the occurrence of *M. lagotis* in the Maranoa area (Roma, St George and Mitchell) provided by references to the common use of the name “bilby snake” for a currently uncommon python, the woma, *Aspidites ramsayi*. The origins of the use of this term are unclear however it suggests that bilbies were present in the area at some time. (Covacevich and Couper 1996)
6. The property “Bilbie Park” is located 60 km south east of Charleville. The property name dates back at least to 1965 when it was split off from an adjoining lease (Qld Lands Department records). A waterhole known as “Bilbie<sup>1</sup> Waterhole” exists on the boundary between “Bilbie Park” and “Noorooloo”. This waterhole is shown on a cadastral map produced by the State Lands Department dated 1936. No evidence of bilbies was found on a trip to the area in April 2004. However, the long history of naming on maps suggests the previous existence of bilbies in the area.
7. In the Eulo area, bilbies were last seen on “Wittenburra” in the late 1960s. (I. Pyke pers. comm. 2003), a long time resident of the area.
8. Two bilbies were reportedly captured between Eulo and Yowah during the construction/excavation of a major east-west gas pipeline in 1984 (Gordon 1990). No evidence was found in the area reported following investigation by P. McRae in 1984-1985, although, there was scattered evidence of rabbit occupation in the area.

### 5.3 DISTRIBUTION DECLINES

Many of these brief natural history accounts provided additional semi-quantitative data on the prior distribution and abundance of the bilby in the eastern areas of the State. The estimates of Southgate (1990b) indicated the limit

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<sup>1</sup> Origins of the word bilby from Brewarrina tribal group in NSW – bilbi, or bilbie (Longman 1922)



of the distribution in 1936 to be in far western Queensland between Windorah and Birdsville (Fig 5.1). The natural history accounts presented here (section 5.2) have enabled this range to be extended approximately 700 km east, to an area just west of Surat on the western Darling Downs. The former distributions estimates provided by Gordon *et al.* (1990) and Southgate (1990b), and current estimate for 1936 from this study are shown in Fig 5.2. The map indicates that bilbies occurred, probably in patches, at least up until possibly the 1940s or 1950s, in the southern central parts of the State, contrasting with that estimated by Southgate (1990b). A quantitative estimate of the temporal rates of decline are summarised in Table 5.1. The area estimates in the Table are total areas and thus include many areas of unsuitable habitat including mountain ranges, rivers and wetlands and thus provide only an index of the total areal distribution of the bilby. They are however useful in indicating changes in distribution over time.

These data suggest that the declines may not have been as dramatic during the 100 years following the description of the species in 1837, as that suggested by Southgate (1990b). This is supported by the fact that the spread of settlement in Queensland didn't start until the late 1840s. Further, foxes only arrived in Queensland in 1910 (Jarman 1986), and rabbits hadn't spread throughout the estimated range of bilbies until the 1920s (Williams *et al.* 1995).

Clearing of the brigalow belt in the central south of the State began in the 1920s, however the process was slow, and hampered by labour shortages during two world wars, the prickly pear invasion and the financial depression in the 1930s (Gasteen *et al.* 1985). They added, that the brigalow areas were not threatened until the second phase of development during the 1950s, when broadscale clearing of the brigalow country using machinery was commenced. It is thus possible that the bilby, a non-specialist, semi-fossorial omnivore, persisted in some of these areas through the period up until perhaps the 1950s, even though no museum specimens or records are able to support this other than that from Surat in 1912.

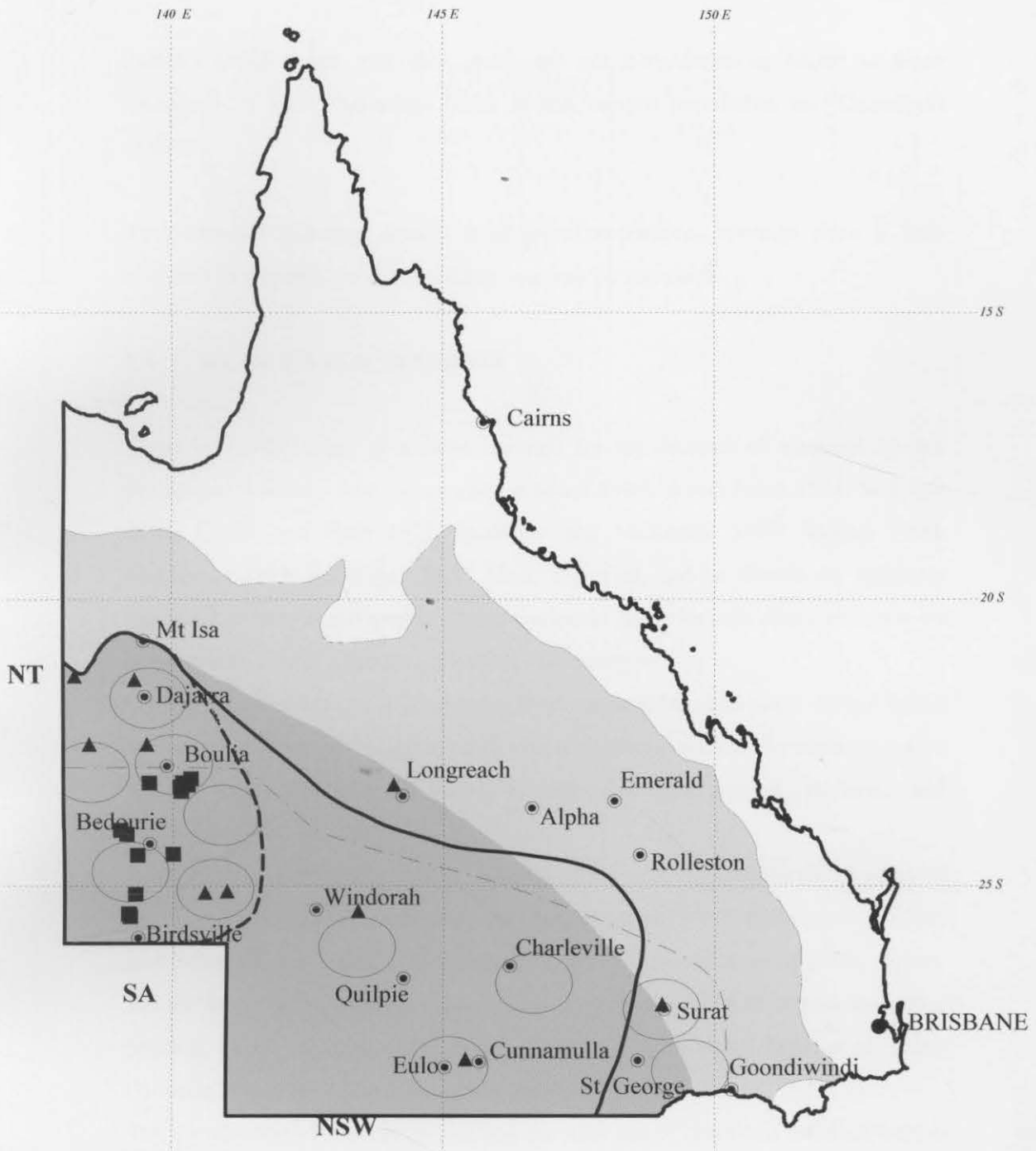
Historical research in the central areas of Queensland could help understand the rates of declines of species associated with the agricultural and pastoral development of the central areas in the State. It is to be hoped that it is not too late

to record some of the oral natural history accounts from this period in Queensland's history.

**Table 5.1 Percentage decline in the range of *Macrotis lagotis* from the estimates for 1836, by Southgate (1990).**

<b>Year</b>	<b>Method</b>	<b>Distribution Area (km<sup>2</sup>)</b>	<b>Percent Decline</b>	<b>Source</b>
<b>1836</b>	BIOCLIM	1 165 000	na	Southgate 1990
<b>1836</b>	Estimated	641 600	Base measure	Southgate 1990
<b>1936</b>	Estimated	156 500	75.6	Southgate 1990
<b>1936</b>	Estimated	588 700	8	This study
<b>1970</b>	Estimated	108 900	83.1	Southgate 1990
<b>1984</b>	Estimated	35 560	94.5	Southgate 1990
<b>1994</b>	Survey	11 390	98.1	This study
<b>1999</b>	Survey	1 679	99.7	This study

Of great concern however, is the current fragmented and restricted range of the species in the far west of the State, and the historical range decline of 99% (Fig 5.1) this situation represents. The core areas of bilbies identified in 1999 (Chapter 4) suggest that if further contractions occur, the population will be restricted to Astrebla Downs National Park and similar ashy plains in the southern areas of "Coorabulka", adjacent to the park. Extant populations still exist north of Birdsville and east of the Diamantina River on Davenport Downs (See Figs 4.4 and 5.1) however, those east of the Diamantina can be considered vulnerable to local extinction due to the 25 km barrier provided by the Diamantina River channels. These are likely to prevent re-colonisation of the area, if threatening processes continue, and are also likely to provide refuge areas for foxes and cats and thus a hostile environment for bilbies. The population north of Birdsville is similarly dis-connected from core areas, however the



- BIOCLIM predicted distribution prior to 1836 (Redrawn from Southgate 1990)
- - - - - Estimated historical distribution (Redrawn from Gordon 1990).
- Estimated distribution 1836 (Redrawn from Southgate 1990).
- - - - - Estimated distribution in 1936 (Redrawn from Southgate 1990).
- Estimated distribution 1936 (this study).
- ▲ Museum and literature records 1800-1950.      ■ Museum and literature records 1950-1980.
- Additional literature and personal communication records this study

**Fig 5.2 Map of Queensland showing revised former distribution of *Macrotis lagotis* in Queensland.**

barriers (sand dunes and clay pans) are not considered as major as those presented by the Diamantina River in the eastern population on “Davenport Downs”.

The statewide historical decline is of great proportions, however there is little evidence to pinpoint the reasons. They can only be surmised.

#### **5.4 REASONS FOR DECLINES**

There is a wide range of reasons reported for the declines of mammal species throughout Australia (see Lucas and Le Souef 1909; Wood Jones 1924; Marshall 1969, Costin and Frith 1971, Burbidge and McKenzie 1989; Morton 1990; Menkhorst 1995; Burbidge 1998.) Most, if not all, can be directly or indirectly attributed to human occupation of the continent. These include direct predation by humans and indirect alteration of habitat in a variety of ways.

Habitat alteration has occurred in many ways, some subtle, and some, not so. Subtle alteration includes the change in patch size attributed to altered fire regimes carried out by aboriginals prior to European settlement, and grazing (Burbidge and McKenzie 1989; Morton 1990).

Less subtle changes have been those associated with the broadscale clearing of native vegetation for the cultivation of cereal crops, plantation timbers and housing and industrial development. Competition from wild populations of goats, rabbits, and the domestic populations of grazing livestock has also had an impact to varying degrees. Exotic predators have had a profound impact (see Clarke *et al.* 1990; Dickman 1996b; Burgman and Lindenmayer 1998).

The introduction of artificial waters and the wide use of chemicals and fertilisers in agriculture have also had a wide range of implications for native species.

Some of the factors considered likely to have contributed to bilby declines include the following:

##### **1. Bilbies as food for Aboriginals**

There are many references to Aboriginal people eating bilbies. Finlayson (1936) was amazed by the quantities of food eaten by individuals:

*"In the matter of food and water there appetites are gigantic, and the quantities of both which they will consume are almost incredible. I have seen two men eat a large kangaroo, at least fifty pounds of meat, at a sitting, which lasted from noon till dusk; and on another occasion an emu was polished off by one man in three sittings. This voracity extends to children as well, and boys of twelve or fourteen will eat twice as much meat and bread at a meal as a hearty white man, and whatever degree of repletion is reached, to refuse food is almost unheard of."*

Roth (1897) observed that *"Bandicoots, porcupines and bilbies (to use a local aboriginal term) are tracked by the aborigines and dug out of their holes in the ground."*, however Krefft (1862) noted that, *"The natives seldom unearth the animal; the holes being very deep, and often found to be uninhabited."*

The following accounts also provide evidence of bilbies being food items:

*"bilbies are fairly numerous"* when referring to foods of the north western aborigines in the "Glenormiston" area (Queensland), which is just to the north west of the present study area. (Coghlan 1895).

*"Its flesh is sweet and much prized by the natives."* (Lucas and Le Souef 1909).

Dent (1972) reported an interview with 87-year old Byron Nathan in 1972, a stockman who had spent his life in the north west of Queensland, and was head stockman at "Springvale" when he saw the bilbies:

*"I've ridden into camps on "Springvale" and on the Burke and seen bilby skins hanging on poles and stretched out on the ground. Once I watched two blackfellows spinning yarn from the fur but I have only twice seen them alive." .....*

*" The last time I saw one alive was in October of that year (1910) when we were camped out with a big mob of cattle near some unusual looking burrows. One of the men guarding the stock late at night thought he saw a shadowy figure hopping around near the cattle before disappearing into the ground. The next day I got a couple of crowbars and with four men decided to investigate. Well it was hard work*

*I can tell you. We dug down over five feet before catching site of our quarry. It was a very big bilby and he was shifting dirt as fast as we were digging.”.....*

*“Even in those days the bilby was on the verge of extinction, because they were considered so valuable by the aborigines they were ruthlessly hunted and had already been banished to the more remote areas of the district.”.*

Waite (1917) found an old skull and observed tracks around Mungeranie west of Innamincka (South Australia) however no other evidence of the species was recorded. He did mention that the aboriginals knew them well. Waite in his expedition with the South Australian to Strzelecki and Cooper creeks in 1916 found that aboriginals were in the habit of digging them up for food, however were doing so less frequently now, (1916), since the introduction of Government supplied rations: “...offers of pipes, tobacco, and sweets producing the usual profusion of promises, but no performances.” (Waite 1917).

Tonkinson (1978) provided additional more recent evidence of the difficulty in digging bilbies out with a photograph of an aboriginal of the Mardudjara of the western desert of WA captioned: “ *Ending a long and tiring dig after the rapidly burrowing rabbit-eared bandicoot (Macrotis lagotis), Minma finally secures his quarry.*”

These accounts all suggest that bilbies were desirable as food items, however were difficult to secure. Finlayson (1961) suggested that the impact of aboriginal hunting on native species was probably minimal in most cases, however should not be dismissed totally for some species. These included Taboo species that may also have had beneficial conservation values for some species. He concluded that even a small hunting population of aboriginals could exacerbate declines of faunal species that occurred at low densities and with restricted ranges.

Many aboriginal communities in remote arid zone areas are still supplementing their diet with wild foods, both plant and animal. This use is usually determined by temporal abundance and a particular fondness for certain species. (Walsh 1991)

Walsh recorded that the Martu people in the Great Sandy Desert of Western Australia still relied on wild foods in 1991, and whilst a wide range of resources

were utilised, most were collected opportunistically and only a small number could be regarded as staples. Walsh added that “..species collected in small quantities, such as grass seeds and the bilby (*Macrotis lagotis*) were still important to some Martu, particularly older people” (Walsh 1991).

## **2. Bilbies used for adornment and decoration by Aboriginals.**

It could be assumed that all or most of the ‘useful’ body parts of prey animals secured by Aboriginals would have been utilised eg flesh, fur, bone and sinews. Different species provided resources that facilitated tool making and keeping warm. Smaller species such as bilbies didn’t offer as many resources additional to meat, which could be provided by larger animals such as kangaroos and emus. It thus makes sense that skins and the tails of many species would have been used for purposes other than eating or keeping warm. Bilby tails in particular, have been widely reported as being used as decorative and ornamental items by many tribal groups across the land. The following quotes attest to this use:

*"not uncommon judging by the number of tails used by the natives as ornaments. They tie the white terminal tufts together in bundles of from twelve to twenty"*  
Spencer (1896).

*Thippa : “a bunch of tassels made from the tails of the native rabbit, and, when washed in damp sand, is very pretty, being white as the driven snow. It takes about 50 tails to make an ordinary thippa, but I have seen some consisting of 350”* (Gason in Curr 1887). Coopers Ck area in the North of SA- Dieyerie Tribe of Australian aborigines.

Roth (1897) reported further, that Aboriginals used a spinning process with the fur to make a twine that was used to adorn their body decorations. Bilby tails were often used also to adorn headdresses, particularly in corroboree dances restricted to women only.

Duncan-Kemp (1952) when describing three types of emu feather shoes used by Aboriginals alluded to the exclusivity and importance of the medicine man’s shoes

thus: *“these are more carefully made, of even size, and are decorated round the top edge with white crests taken from the tails of rabbit bandicoots, or failing these, with feathers plucked from some living nocturnal bird.” “...bandicoot embellishments protect the wearer-always the Medicine Man - for the use of these shoes is banned to ordinary folk”*

This also suggests the difficulty in procuring these animals – either not many, or hard to get. Given the deep nature of bilby burrows and difficulty in digging them successfully out, one is tempted to conclude that this might be the reason they were so important and used in ceremonies and for special purposes such as shoes for the spiritual leaders of tribal groups.

Burbidge *et al.* (1988) reported that bilbies were hunted by digging out burrows and occasionally spearing at the burrow entrance. They also refer to the use of tails as decorative ornaments by both men and women. Moreover, that the species was an important food item and still eaten by some groups at the time.

One of Australia’s foremost anthropologists, T.G. Strehlow, on the last day of his life in 1978, is reported as referring to bilby tails as ornaments of some ceremonial significance in the following lengthy, though moving quote from Hill (2003):

#### The Bridal Headpiece

*“...Thus seated, it was the moment for the presentation. Justice Kirby had praised Strehlow and the auspicious occasion, words that had prompted the delighted Strehlow to offer him a copy of the exhibition catalogue. It was a thing of beauty.*

*On the cover was a magnificent photograph of a bridal headpiece. It was made of bandicoot tails-black and white and brown-photographed against a glowing, blood-red background. The tails were fixed with black spinifex gum, human hair string and bound with kangaroo sinews, and they made a spray, a vigorous bristle of a fan. Thirty animals had been killed to make it, Strehlow told Kirby. The animal, *ingkaia* (the rabbit-eared bandicoot; today we call it the bilby), was almost extinct by the early 1900s. He was displaying the tail tips of the animal, the *albetja*.’*



*'I asked him to describe the cover of the program,' Kirby remembers, 'and he told me that it was a bridal decoration in the Aranda tribe. He then began to speak as if in metaphors about the bandicoot tail that is demonstrated in the decoration. And it was as if he was going off into a realm of poetry, because he began to say that the bandicoot was no more. The bandicoot had been driven out of the Australian Centre by the rabbit, introduced by the white man, and the metaphor was very vivid. It was the bandicoot with the original Aboriginal people, the rabbit was the invading white man. And as he said **ingkaia** he seemed to collapse, and it was as if it was gurgling out of him. **Ingkaia**, he said ... and at that he simply expired. And there was a desperate endeavour to revive him but he died, and he died in my arms. '...'* (Hill 2003), (bolded words by me).

The fact that bilbies were used in this fashion by Aboriginals I suggest relates to the difficulty in procuring bilbies, and not necessarily their abundance. The attachment of ceremonial significance to the animal by adornment with the strikingly bi-coloured tails lends support to the specialty of such a resource.

Aboriginal use of bilbies has probably had a minimal impact on bilby declines over the past 160 years in Queensland.

### **3. Bilbies as food for early European settlers.**

Aboriginal guides who were familiar with the land and the species it contained accompanied most of the early explorers and naturalists. It could be assumed that they shared their dietary customs with their European party members, and allowed many to partake in the eating of many native species, perhaps for the first time. Evidence for this is provided by the following accounts by Gilbert and Gould in 1863:

*"That its flesh is sweet and delicate, I have abundant testimony. When boiled it resembles that of the rabbit; prejudice would therefore be the only obstacle to its general adoption as an article of food"*(Gould 1863).

John Gilbert, who provided many of the specimens for Gould's early work on mammals in Australia, also added testimony to the taste of the bilby:

*"The flesh is extremely delicate, and when boiled greatly resembles that of the common rabbit"* (Gilbert 1863 in Whittel 1954)

Finlayson (1936) provided further testimony to this custom 73 years later, when he alluded to the interest in the mammals of central Australia: "...because they form the mainstay of the black man's diet and make important contributions to that of the travelling white man too. It is remarkable how, after a week or so of damper and tea, persons who ordinarily have little leaning towards mammalogy, will develop a keen and even anxious interest in that study; and will inquire plaintively of their blacks regarding the possibility of augmenting the pot with a tasty *tchungoo*, a tender if grotesquely shaped *talgoo*, or even, in extremis, the greasy, insectivorous and therefore weirdly smelling, *wintaroo*." (bold by me).

The three species referred to – ‘tchungoo’ (Burrowing bettong, *Bettongia lesueur*), ‘talgoo’ (bilby, *Macrotis lagotis*) and ‘wintaroo’ (the Golden bandicoot, *Isodon auratus*), were once widespread and are now all endangered species. *B. lesueur* has disappeared completely from mainland Australia and now occurs only on Bernier, Dorre, Barrow and Boodie islands off the coast of north Western Australia. (Burbidge 1995).

Marshall (1966), referring to the epicurean delights provided by some of our native mammals in the course of Gould's travels 1838-40, offered the following -

*"Nevertheless all this eating of animals did little harm. The early settlers were coast bound, or almost so, and their culinary inroads on wallaby, bilby, bandicoot and 'badger' did no more than deplete local populations in the vicinity of the settlements. These men were chronically short of protein, and no-one can blame them for eating what they could get."*

*"Many new settlers ate more kangaroos than sheep ..."* (Jenkins 1974).

*"The kangaroo, the euro, the rock-wallaby, and the emu, are the big game, the red meat, of the Lords of the land, who take little active interest in small fry. Upon their gins devolves the constant task of digging out the smaller mammals to supplement the larder, and from them a wealth of material and data may be obtained which is otherwise most difficult of access."* (Finlayson 1936).

Kangaroos were much more abundant and readily procurable than bilbies. Further the nutritional returns obviously were substantially different, and kangaroos are thus likely to have contributed a much greater proportion of the diet of early settlers. The commercial harvesting of kangaroos for pet food and human consumption continues today and forms an important part of the economies of several States in Australia.

I suggest the impact of early settlers eating bilbies would have been of little significance to the subsequent range declines observed since settlement.

#### **4. Pest destruction by early European settlers.**

In Queensland, a series of Marsupial Destruction Acts were in force from 1877-1930 (Hrdina 1997). These involved bonuses being paid for the destruction of 'vermin' that included a wide range of macropodid, rodent and bandicoot species as well as foxes and dingoes. During this period over 27 million animals were destroyed under the series of Acts enacted, with the prime purpose of 'vermin removal'. Between 1886 and 1929 approximately 1.3 million small marsupials were taken under these Acts. 'Small marsupials' included rat kangaroos (referred to as kangaroo rats), pademelons and bandicoots (Hrdina 1997).

The data reveal that kangaroo rats were the most targeted species on the Darling Downs (an area that encompassed the towns of Toowoomba, Goondiwindi and Miles). For example, the number of kangaroo rats and other species (combined) totalled 73154 during the period 1896-1929. Bandicoots and pademelons contributed less than 150 to this total for 11 years of records. This was also the case in the western division, a large area that extended from Clermont and Longreach in the north, to Quilpie and Adavale in the west, and Miles and Surat in the east. In this area, kangaroo rats and pademelons appeared to be the most abundant and targeted species, although bandicoot take was substantial in some years. For example, 49 700 bonuses were paid for kangaroo rats over 10 years, and 107 977 pademelon bonuses were paid in 1897 alone; 7094 bandicoots were also taken in the same year. Total 'other species' of small marsupials for the western district during 1896-1929 was 180587 bonuses. In the 'Downs' region a total of 25208

'other species' were taken over the same period. The highest takes were in the period 1896-1901 (Hrdina 1997).

Hrdina only reports data up until 1930 when the acts were replaced by, 'The Grazing Districts Improvement Act of 1930', however the data reveal a substantial 'take' of small marsupial species, particularly the smaller macropods. Bandicoot 'take' was less substantial and possibly related to the reduced perceived threat of these species to grazing and agricultural enterprises, rather than abundance. Bilbies are likely to have escaped much of this abhorrent period of human 'vermin' destruction due to their strictly nocturnal habits and diurnal shelter in deep burrows.

##### **5. Bilbies used in the fur trade by early settlers.**

The title of one of Marshall's chapters in his famous book "The Great Extermination" (1966) is titled "On The Disadvantages of Wearing Fur". In an evolutionary context, it made little sense, in an exploitative human context, is important and poignant.

A fur trade for many species was established quickly in the newly settled continent in the late 1770s as a new suite of furred animals was discovered. It still continues today, although in a much more controlled and sustainable fashion.

Wood Jones (1924) reported that bilby "*pelts marketed in skin sales in Adelaide in large numbers*", and Jenkins (1974) provided similar evidence from the Avon Valley in Western Australia in 1930 : "*Many new settlers ate more kangaroos than sheep and made pocket money from ...a variety of skins ... ..cats and dalgites<sup>2</sup> at 1/- to 3/- per doz.*" .

Bilby skins were apparently not entirely successful in the fur trade as a result of their lack of strength and particularly their characteristic 'musty' odour, which was apparently unacceptable (Jenkins 1974).

A fur trade was not associated with the pest destruction accompanying the Marsupial Destruction Acts referred to above (point 4). Under these Acts the sale of skins was not permitted (Hrdina 1997). A koala skin fur trade however, was

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<sup>2</sup> 'dalgite' is one of the many common names for the bilby, particularly in Western Australia.

well established throughout Australia in the early 1900s. Troughton (1948) reported that in 1924 more than 2 million koala skins were exported from the eastern States and Wood Jones (1924) gave figures of 205679 for 1920-1921 in South Australia. Perhaps the 'darkest' period of the Australia's fur trade occurred in Queensland during August 1927: an open season resulted in 101 4632 possums and 584 738 koalas, being taken (Marshall 1966).

There is no evidence to suggest a trade existed for bilby skins in Queensland. Why such a trade occurred in South Australia, and to a lesser extent in Western Australia is unknown.

## 6. Disease

Diseases have periodically had large local impacts on some species of mammals that have resulted in local dramatic population declines (see Abbott 2001; Le Souef 1923).

It is unknown if any disease epidemics are associated with bilby populations in Queensland, either present or past. Bodetti *et al.* (2003) reported the existence of sub clinical chlamydial pathogens from a reintroduced population of bilbies in Western Australia. No other disease accounts are currently available.

## 7. Fire

*"There was another instrument in the hands of these savages which must be credited with results which it would be difficult to over-estimate. I refer to the fire-stick; for the blackfellow was constantly setting fire to the grass and trees, both accidentally, and systemically for hunting purposes.*

*Living principally on wild roots and animals, he tilled his land and cultivated his pastures with fire: and we shall not, perhaps, be far from the truth if we conclude that almost every part of New Holland was swept by a fierce fire, on average, once in every five years".* (E. Curr 1883 in Latz 1995).

Fire has shaped Australian ecosystems for perhaps the entire period of human existence on the continent. There exists a great amount of literature that relates changing fire regimes since European settlement to changes in vegetation

structure and species composition (see Jones 1969; Latz 1995) The dominance of so-called fire resistant species has been mostly reported from central Australia and there is little literature that is relevant to the ecosystems of southern inland Queensland. Johnson (1989) suggested that the European changes to fire regimes employed by aboriginals in central Australia was, in combination with droughts, introduced predators, and competitors, responsible for the spectacular decline in bilbies.

## **8. Fox and rabbit**

By the early 1930s rabbits were in plague proportions in south western Western Australia and extensive control programs that included netting, poisoning with pollard and phosphorus and burrow fumigation and ripping resulted in the bilby often being an unintended victim (Jenkins 1974).

Rabbits arrived in Queensland in 1890 and were widespread throughout the bilby's historical eastern range by the 1920s (Williams *et al.* 1995). The ecological impact of the rabbit invasion in Australia is well documented (see Rolls 1969; Williams *et al.* 1995; Coman 1999; Low 1999). Losses of perennial plants and changes in plant species composition are likely to have had indirect impacts on food availability for bilbies as a result of decreased invertebrate herbivores. Direct competitive impacts are unknown, however there is evidence that the pugnacious nature of rabbits may have provided competitive benefits over species such as the burrowing bettong, *B. lesueur* and rufous hare-wallaby, *Lagorchestes hirsutus* (Williams *et al.* 1995). Rabbits do not compete for food with bilbies however their higher reproductive output is likely to indirectly impose food-limiting stresses on bilbies at a local level, due to reduced plant survival and recruitment, and a resultant loss of invertebrates.

There are no reports that document a similar impact on bilbies in Queensland however it could be reasonably assumed the impacts were likely to be as dramatic as experienced elsewhere. These impacts of rabbits are likely to have occurred in the historical range of bilbies in eastern Queensland. Rabbits probably achieved highest densities in areas that were opened up for grazing in the early 1900s. The

extensive rabbit netting programs that were conducted throughout these areas, as rabbits become a problem, provides evidence. Coman (1999) estimated that nearly 50 000 km of Government subsidised and private netting fences occurred in Queensland in the late 1880s and early 1920s.

The decline in rabbit numbers after the introduction of myxomatosis in the 1950s may have allowed any existing bilby populations to recover. However rabbits quickly become resistant to the myxoma virus (Williams et al. 1995), and foxes probably quite rapidly decimated any remaining bilbies.

That introduced predators have had an enormous impact on our unique native species has been appreciated for some considerable time (see Gould 1863; Wood Jones 1924; Finlayson 1936, 1961; Glauert 1955; Marshall 1966; Rolls 1969; Kinnear *et al.* 1988; Saunders *et al.* 1995; Dickman 1996b). John Gould commented in 1863 thus:

*“ Short-sighted indeed are the Anglo-Australians, or they would long ere this have made laws for the preservation of their highly singular, and in many cases, noble indigenous animals; and doubly short-sighted are they for wishing to introduce into Australia the production of other climes ....”*

Frederick Wood Jones (1924) provided an indication of the disturbing impacts of the arrival of the fox in Australia: *“From a zoological point of view the fox probably represents the most baneful disturbing influence brought about by the human folly of introducing animals into a new country”*

*“there is certainly no part of this state where the bilby is not a rapidly disappearing animal”*

He added that the absence of foxes in central Australia, but an extraordinary abundance of rabbits, had impacted on bilbies.

Foxes didn't arrive until 1910 (Jarman 1986), about 20 years after rabbit's arrival, and possibly simply provided a final deadly blow to the already disturbed populations of many native species. Bilbies because of their semi-fossorial existence are likely to have survived the depredations of the fox longer than other terrestrial small to medium sized mammals.

The threat that the fox poses to the fragmented extant population of bilbies will be discussed in Chapter 6.

## **9. Land Clearing**

Wholesale clearing, and the arrival of the fox, played a part in the demise of the bilby in Western Australia (Jenkins 1974). The extensive clearing of areas on the Darling Downs for agriculture in the early 1900s, and the brigalow areas further west in the 1950s, no doubt had a massive impact on bilby numbers. The use of large machinery in the brigalow areas in particular, impacted heavily on plant communities (Covacevich and Couper 1997), and I suggest would have impacted equally heavily on bilby burrows and their occupants.

Clearing is still occurring throughout much of the bilbies former range in the east of the State, though the bilby has long since gone.

## **10. Water**

An indirect but common element to many of these abovementioned factors is water. Human settlement required water, agricultural and pastoral development required water, and exotic predators and competitors benefited from additional water.

The introduction and provision of artificial water to the western landscape will be explored in greater depth in the Chapter 6.

## **5.5 SUMMARY AND DISCUSSION**

Troughton (1948) reported of the disappearance of the bilby from New South Wales in the following way:

*“ ... and apparently the last record of the bilby's occurrence in the State is provided by my colleague, K.C. McKeown, who had a pair under close observation in the rocky hills on the Wagga Experimental Farm, for about five years prior to 1912, when they were unfortunately killed by “sportsmen” from the town, to the intense regret of his father, then manager of the Farm”.*



*“ In such areas of intensified settlement the native fauna must inevitably give way. But it is truly unfortunate that the depredations of the introduced fox, the spread of rabbits followed by the poison trail, and the inexcusable actions of thoughtless people, should have swept this interesting and useful creature from the more settled areas of New South Wales”.*

Direct human exploitation of the bilby does not appear to have been the major reasons for decline of the bilby in Queensland as was the case in Western Australia (Abbot 2001).

A series of events appear to have combined to make large areas unsuitable for bilbies in the years following European settlement of the State. This impact is likely to have been greater in the southern areas that were first disturbed by early settlers in the mid 1850s. These areas were also the first exposed to the invading populations of rabbits and foxes emanating from southern States 50 years later. Wholesale land clearing on top of this in the 1950s, 1960s and 1970s may have provided the first introduced straw for domestic livestock, but appears to have been the last for many native species, bilbies included.

The absence of substantial data on the historical distribution and temporal declines in Queensland made interpretation of causal factors difficult. The only option left, apart from a detailed searching and analysis of anecdotal and historical accounts, was to look at the current distribution of the bilby with good data sets, and try and determine what processes haven't occurred in these areas.

Land use changes in the current study area and the presence of exotic predators, continue to pose a very real threat to continuing population declines of bilbies. These threats to the extant population are discussed in the following Chapter.

# CHAPTER 6

## *THREATS TO THE QUEENSLAND POPULATION OF BILBIES*

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### 6.0 INTRODUCTION

Australia has an unfortunate record of species losses and declines. Mammals in the critical weight range of 35-5500g identified by Burbidge and McKenzie (1989)(but see Cordillo and Bromham 2001) have disappeared from many areas, declined to fractions of their former range, and some now exist only on islands where exotic predators are absent (Jarman and Johnson 1977; Kinnear *et al.* 1988; Burbidge and McKenzie 1989; Johnson *et al.* 1989; Robertshaw and Harden 1989; Morton 1990; Dickman 1992; Short *et al.* 1992; Dickman *et al.* 1993; Gibson *et al.* 1994; Serena 1994; Smith and Quin 1996; Sinclair *et al.* 1998). In the short period of European settlement 17 species of mammals (12.4%) have become extinct, and 24 have declined in range (Burbidge and McKenzie 1989).

The focus of this chapter is on the processes threatening current bilby populations in Queensland and expands on the broad impacts discussed in the previous chapter. The chapter draws attention to three exotic predators, the European red fox *Vulpes vulpes*, dingo *Canis lupus dingo*, feral cat *Felis catus*, and land management practises that pose the greatest threat to extant populations of the bilby in Queensland.

Much of the work, observations and discussion in the chapter are based on work carried out at Astrebla Downs National Park (See Fig 2.1).

### 6.1 THE EXOTIC PREDATORS

### 6.1.1 Fox, *Vulpes vulpes*

*Positive impacts* – none.

#### *Negative impacts*

The European red fox is widespread in most of Australia except for the northern tropical areas (Saunders *et al.* 1995). It was introduced around 1845 in Victoria and released to areas near Geelong and Ballarat 15-20 years later (Rolls 1969). Within 30 years of the initial release the species was declared a pest in some shires of northeast Victoria (Saunders *et al.* 1995) and by 1924 Wood Jones had observed that:

*"From a zoological point of view the fox probably represents the most baneful disturbing influence brought about by the human folly of introducing animals into a new country".*

The spread of the fox across continental Australia was closely associated with the invasion of rabbits across the landscape (Jarman 1986) and has been implicated in the greatest losses of Australian native fauna during the past 120 years (Kinnear *et al.* 1988).

The fox has been implicated in the decline of the bilby by many authors (Wood-Jones 1924, Glauert 1955, Finlayson 1961, Watts 1969, Burbidge and McKenzie 1989, Southgate 1990b, Abbott 2001). Saunders *et al.* (1995) listed 23 species of mammals considered to be at risk from fox predation, including the bilby. However the records of bilbies actually being taken by foxes are few (see Southgate and Possingham 1994; Paltridge 2002).

Burbidge and McKenzie (1989) suggested the fox might not have been involved in the initial declines of mammal species, but that it appears to have contributed to current declines, particularly of remnant populations.

The areas currently occupied by bilbies in Queensland are largely devoid of foxes, although the species occurs within approximately 150 km, in all directions from the study area (personal observations).

It would appear that foxes have historically been either absent or in very low densities on the ashy and mitchell grass plains. Tom Tully, a long time resident of the channel country,

respected gentleman and manager of Springvale station for 14 years had never seen a fox in the area (T. Tully pers. comm. 1993). The manager of Davenport Downs, Noel Merrin similarly reported in 1993 that he had not seen foxes on the property.

The reliability of non specialist or 'non-interested' people's records of native fauna, particularly small mammals is not good, however people on properties are generally very aware of exotic species such as fox, dingo, cat and rabbit, and I thus have no doubt as to the reliability of these reports.

Mahon (1999) recorded foxes for the first time in 1991 in the northern Simpson Desert, approximately 150 km west of the current study site, following rodent irruptions in his study area.

The fact that the fox occurs, albeit in low numbers, in close proximity in virtually all areas surrounding existing bilby populations suggests that some factor is limiting fox incursion into these areas.

Saunders *et al.* (1995) reported that more open, uniform habitats are less favoured by the species, and that abundance increases in fragmented environments where there is a wide variety of food, cover and den sites. Catling and Burt (1995) also reported the tendency for foxes to inhabit forests in close proximity to highly disturbed grazing and agricultural land in eastern Australia. The currently preferred habitats of bilbies in Queensland are flat open and sparsely vegetated plains (see Section 1.3). These are likely to be unsuitable for the fox. However, the timbered drainage lines that permeate these areas would provide suitable cover and den sites. The stony plains habitat of the bilby between Birdsville and Bedourie lie adjacent to the dunefields of the Simpson Desert where Mahon (1999) and C. Dickman (pers. comm.) have found foxes abundant at times. The sand dune habitats offer a great deal more cover than the open plains and are thus likely to be preferred by foxes; however, it is surprising that foxes do not appear to disperse along drainage lines and hunt at least along the fringes of the open plains.

The same situation applies in the clayey plains habitat of the bilby. These plains drain into the major rivers of the region, the Diamantina in the south and the Hamilton in the north. The major creeks running into these rivers are timbered and could also be expected to provide adequate cover and den sites for foxes. These areas form dispersal corridors for

feral cats that venture out onto the open plains when food is abundant (R. Palmer unpublished, P. McRae personal observations). Why foxes have failed to occupy these areas is unknown.

There is considerable anecdotal evidence, but little scientific, that suggests dingoes exclude foxes from local or regional areas. Williams *et al.* (1995) reported that foxes appeared to be displaced by dingoes and only occurred in low densities where dingoes were present. The current distribution of foxes is similar to that of rabbits but appears to be limited in some areas of Western Australia by high dingo density (Saunders *et al.* 1995). However, there are a number of studies that report the fox, cat and dingo as co-existing (Jarman 1986; Catling and Burt 1995; Saunders *et al.* 1995). Saunders *et al.* (1995) suggested that in some areas the dingo is responsible for regulating fox density rather than distribution.

The historical spread of the fox out of Victoria has been reported by Jarman (1986) and Rolls (1969), however there are few published accounts that quantify numbers and densities associated with the spread; most data have been presence/absence.

Some numerical evidence is available as a consequence of statewide bounty schemes for mammals that existed in some States in the late 1800s and early 1900s.

In Victoria a bounty scheme on foxes began in 1949 and continued until 1977 (Saunders *et al.* 1995; Menkhorst 1995). Studies by Redhead *et al.* (1991, in Saunders *et al.* 1995) indicate that approximately 45 000 foxes were taken between 1951-1952 in Victoria under a bounty scheme.

In Queensland, a series of Marsupial Destruction Acts were in force from 1877-1930 (Hrdina 1997). These involved bonuses being paid for the destruction of 'vermin' that included a wide range of macropod, rodent and bandicoot species as well as foxes and dingoes. During this period over 27 million animals were destroyed under a series of Acts. Seven years of these bonus records between 1918 and 1929 indicate that of 75 455 foxes were destroyed across the State (Hrdina 1997). Hrdina reports data only up until 1930 when the Acts were replaced by 'The Grazing Districts Improvement Act of 1930'. Since then, the data

has not been compiled or published, and probably reside within reports of the State Lands Department.

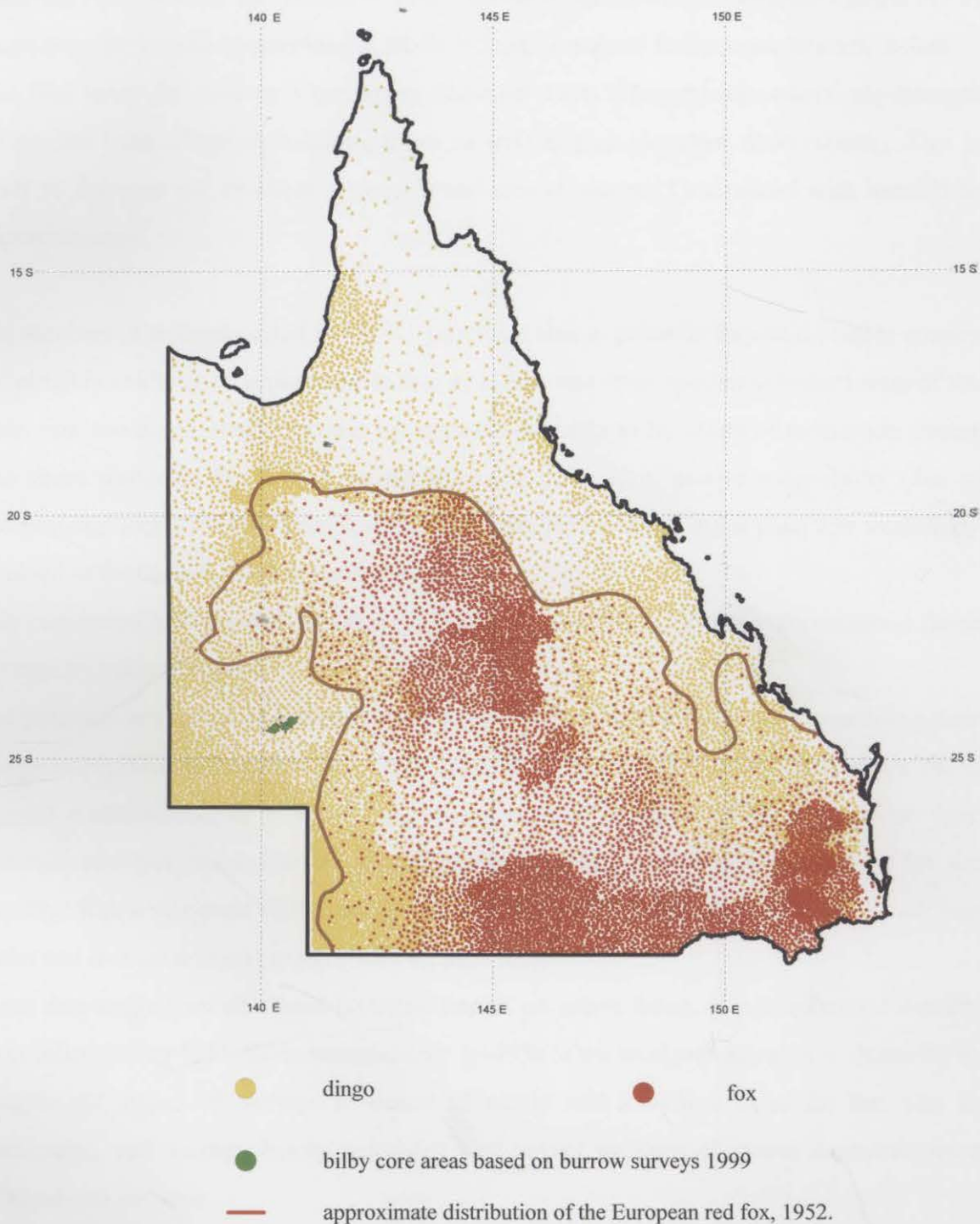
A copy of the Annual Report on the operations of 'The Stock Routes and Rural Lands Protection Acts, 1944 to 1951' for the year 1951-1952 does contain some hand drawn spatial data on the distribution of fox and dingo scalp returns. These were digitised during the course of the present study, and are presented in Fig. 6.1. Each dot represents five scalp returns which when added together total: 34 530 foxes and 45 955 dingoes for the year.

The data show the distribution of both species at the time and clearly indicate the spatial separation between them. The map also provides a quantitative index of the densities of both species at the time, and supports the suggestion that where dingo numbers are high, foxes are either absent or in very low numbers.

The reason for this apparent separation could be attributed to a number of factors. It could reflect separation based on habitat preferences, although this is unlikely across the statewide ranges of both species. The low densities and absence of dingoes in the southern central areas (Fig 6.1) (approximately between Windorah and Goondiwindi) is possibly explained by intensive, dingo-targeted control in sheep grazing areas, but cannot be explained by physical exclusion provided by a 5 680 km Dingo Barrier Fence, which was erected under an Act of Parliament in 1954 (Percival and Westney 1989).

The fox appears not to be able to successfully inhabit wet tropical areas of the north of the State (Jarman 1986; Southgate 1990). Corbett (1995) reported some dietary overlap between foxes, dingoes and cats and suggested that in the arid zone dingoes survive droughts longer than the other two species by out competing them for scarce food resources. For example, dingoes were observed defending livestock carcasses. The data presented in Fig 6.1 appear to suggest that dingoes and foxes are spatially separated by a combination of factors including habitat suitability in certain areas, dingo control in the sheep areas, and possibly competitive exclusion of foxes by dingoes in certain areas of shared habitat, in the far west. This suggestion needs to be tested.

Dickman (1996b) suggested that a decrease in world markets for exported fox skins in the late 1980s resulted in an increase in fox populations. This was apparent in the Charleville



**Fig 6.1 Distribution of the European red fox and dingo in Queensland 1952.**  
 (Data aggregated and re-drawn from Queensland Department of Lands records 1952).

Note : Data from bounties paid on scalp returns. Each dot represents 5 scalps.

area of western Queensland where prices of up to \$45 were paid for fox skins in 1984-85. Fox numbers increased dramatically once the market price fell in the late 1980s (personal observation). However, the extensive 1980 baiting program that is currently carried out in dingo areas in western Queensland is likely to have contained the increase to some extent. This has been the case at Currawinya National Park (Hungerford) where pig-strength baiting has been effective in killing foxes as well as pigs (personal observations). This is likely to decrease fox numbers across a broad area of western Queensland with benefits to the native fauna.

The numbers of foxes depicted in Fig 6.1 provide a clue to potential impact on native species and possibly evidence to explain the decline of bilbies and other species in eastern areas of the State. Fox and dingo numbers could be expected currently to be orders of magnitude greater than those shown in Fig 6.1, given the time (53 years ago), greater accessibility (due to transport and lack of land clearing), effort (more people involved in the past) and technology involved in the control measures at the time.

This population of foxes adds credence to the substantial, broadscale impacts on native fauna reported by many observers.

The potential impact of these numbers of foxes can be put into context by examining their energy requirements. Saunders *et al.* (1993) reported that an adult male fox requires 372 g of wild mammal/day, or 524 g of scavenged meat. Paltridge (2002), using these food demands, reported that a 300-400 g sand goanna *Varanus gouldii* would sustain a fox for one day, whilst Sargeant (1978 in Saunders *et al.* 1995), estimated that a family of two adults and five cubs would require 18.5 kg km<sup>-2</sup> /day.

These data suggest an enormous potential impact on native fauna. If it is estimated that the foxes killed during 1951-52 represented only 10-15% of the total population, it is shattering to imagine the impact of perhaps in excess of nearly half a million foxes for that year in Queensland, and further, hardly surprising that severe declines of native mammals have occurred and continue.

The fox doesn't occur currently in the extant range of bilbies in Queensland. That this situation exists is fortuitous, but is also critical to the persistence of the bilby, given the



ecological success the fox has shown in a wide range of environments in Australia. If incursion of the fox into the current range of bilbies occurs, population declines could be rapid.

The absence of the fox in bilby areas probably results from a series of complex factors that have resulted in bilby persistence in small areas that are either unsuitable for foxes, or they are perhaps being excluded by dingoes.

### **6.1.2 Dingo, *Canis lupus dingo***

#### *Positive impacts*

The dingo, a larger predator than the fox, presents an interesting and different situation to that of the fox owing to its longer, 4000-5000 year history of occupation of the continent (Corbett 1995). In that time it is likely to have contributed to the extinction of the Tasmanian devil and thylacine on the Australian mainland. Although many authors directly link the thylacine's extinction on the mainland to the dingo (Calaby 1971; Archer 1974; Morton 1990; Flannery 1994), Paddle (2000) suggested the dingo simply augmented the impact of aboriginal hunters on the thylacine, by hunting co-operatively with them. The dingo remains the largest mammalian predator and due to its relatively short period of evolutionary history in Australia, I regard it as exotic. Even so, it is reasonable to expect that some ecological balance with native species has been reached. The extinction of the thylacine could hardly be recognised as a positive impact of the dingo, however in the bilby context some impacts of the dingo can be regarded as contributing to the persistence of the species, or at least decreasing its rate of decline, in Queensland.

Wild populations of dingoes occur throughout most of mainland Australia (Corbett 1998), are widespread, and prey on bilbies in the present study area (personal observations; R. Palmer unpublished).

The impact of dingo predation is confounded by the ecologically complex interactions between it and the other two predators, the fox and cat. The interaction between the dingo and fox, which occurs sporadically adjacent to bilby areas, could be critical if the dingo is preventing establishment of high densities of foxes. In this scenario dingo numbers in low

densities could be beneficial. If, however, dingoes are preying on bilbies at critical times the impact could be greater. This supports the general tenet that even low predation rates by foxes, dingoes or cats could impact on threatened species (Burbidge and McKenzie 1989; Morton 1990; Saunders *et al.* 1995; Dickman 1996a,b; Abbott 2001). The impact of dingoes during times of severe drought is probably reduced due to their low numbers. This allows bilbies to survive and recruit by feeding on subterranean food resources.

The dingo possesses a number of ecological and behavioural attributes that are likely to be of less consequence to bilbies than those possessed by foxes or cats. These include larger body mass, larger home ranges, reliance on water, out competing foxes and cats during droughts (defending carcasses and preying on cats) and, importantly, a preference for larger prey (Corbett and Newsome 1987; Corbett 1988, 1995; Newsome and Coman 1989; Thomson 1992a,b; Saunders *et al.* 1995; Dickman 1996a).

Home ranges of dingoes in the study area are unknown, however tracks of individuals have regularly been followed for 14 km between two bores and up to 35 km on occasions (personal observation). These observations suggest that dingoes have large home ranges in the area. Corbett (1995) reported a mean home range size of 67 km<sup>2</sup> in the Simpson Desert just east of the current study area. The reported highly structured social organisation of dingoes (Corbett 1988, 1995; Thomson 1992b), coupled with the large home ranges likely to occur in the area, suggest a limited number of dingo packs could be supported at least in Astrebla Downs National Park.

Also, dingoes must drink approximately 12% of their body weight /day in summer and 7% in winter (Newsome and Coman 1989). This dependence on water has been shown to limit the establishment of packs (Corbett and Newsome 1987; Thomson 1992a). For example, Corbett and Newsome (1987) reported that of 21 dingo natal dens identified during a 9 year study in the arid north of Western Australia, 47.6% were within 0.5 km of water, and only 19% were greater than 2.5 km from known water.

Corbett (1995) summed up the living area requirements of dingoes by suggesting that the size of most living areas is determined by a trade-off between dingo density and availability of

food and water resources. He added that if food is abundant and procurable in cooler months, animals can apparently absorb sufficient free and metabolic water from their prey to be able to survive in the absence of surface water. However, they need to return to more reliable water sources when it either becomes too hot or food abundance declines.

Given all of the above, dingo densities are seldom likely to be high under natural situations in the study area. The addition of livestock and artificial waters is likely to have changed these dynamics. However, densities were low throughout the bilby burrow areas surveyed in 1994 and 1999 (Chapter 4) (P. McRae unpublished). This is probably related to reduced densities as a result of control programs carried out in many areas.

Corbett (1995) suggested that dingoes develop a search image for prey and don't switch readily in response to prey collapse, but will die rather than take other species. This could be advantageous to bilbies during irruptions of the long-haired rat *Rattus villosissimus* that occur infrequently after successive seasons of above-average rainfall.

#### *Negative impacts*

As a large predator with a dietary preference for larger sized mammalian prey (Corbett 1995), the dingo presents a threat to bilbies. Bilbies have been recorded in stomach contents and scats from dingoes at Astrebla Downs National Park, making up approximately 8.6% of their diet in a study that included the current study site (R. Palmer unpublished). This level of predation on a prey population that is small and fragmented could be significant.

Dingoes breed in the winter months and thus the lactation demands of females occur at a time when invertebrates and reptiles are least active (Thomson 1992a). This could exert pressure on mammals, including bilbies, in the winter.

Corbett (1995) reported that dingoes regularly include rabbit warrens in their regular hunting circuits and hunt alone to catch rabbits. Dingoes were observed to travel similar circuits in bilby areas and seem to visit individual burrows frequently, as evidenced by tracks at burrow entrances. Attempts at digging burrows out have also been observed, however most of these attempts have been unsuccessful judging by the depth of diggings. Bilby burrows appeared to

be too deep, and the substrate too restrictive, to allow successful excavation by dingoes (personal observations).

Dingoes consume approximately 7% of their body mass/d, or approximately 1kg /d (Green and Catling 1977). This is an average size for an adult bilby, and provides a clue to the potential impact of dingoes on bilbies if they were more readily available, selectively predated and procurable.

To summarise: dingo predation on bilbies is probably minimal, however, since bilby populations are small and fragmented, long term predation could result in a series of local extinctions of bilby populations, particularly those associated with timbered drainage lines, and simply delay the entire extinction process. In the short term it is suggested that low-density dingo populations are possibly preventing the establishment of foxes in the area. This is also perhaps simply preventing a more rapid decline, to that which may occur if foxes were present.

### **6.1.3 Feral Cat, *Felis catus***

#### *Positive impacts*

*“Nothing good can be said for feral cats. Get rid of them. ( Rabbits can be controlled in other ways other than predation)”* Newsome (1991).

#### *Negative impacts*

The impact of feral cats on Australian native species has been comprehensively reviewed by Dickman (1996a). He flags the bilby as being one of the species at a high risk because of it's susceptibility to impact from cats based on the following criteria: cat density, body mass, habitat use, behaviour, mobility and fecundity. He further identifies the Queensland channel country as the second highest priority area in Australia for investigating the impact of feral cats based on the number of endangered or vulnerable species present.

Whilst at this stage no quantitative data are available on cat predation rates on *M. lagotis* in Queensland, there is a mounting body of unpublished data to suggest that potential impact in certain circumstances could be high (this study; R. Palmer unpublished).

A brief summary of some aspects of cat ecology within the study site is presented below.

#### *6.1.3.1 Distribution and Shelter sites.*

Feral cats are frequently encountered in the study area and have been observed to seek diurnal refuge in coolibah trees which are scattered along the three major drainage lines that occur within the park i.e. Curica Creek, Warra Creek and Backwards Creek (see Fig 2.1). In these situations cats occupy tree hollows, the nests of raptors, or simply rest on a fork or enlarged flattened trunk or branch. They have also been observed sheltering in debris that has built up around the bases of trees and fallen timber in and along the margins of creeks, and in large mitchell grass tussocks on adjacent open plains. A female and litter of seven kittens were observed in the upper reaches of a bilby burrow in 1989. Cats have often been observed retreating into bilby burrows at night (personal observations).

#### *6.1.3.2 Breeding and Body Mass*

Cats were observed to be in breeding condition on virtually all trips to the area that resulted in specimens being taken. Kittens and/or embryos were observed in March, April, May, June, July, August, October and November. These data are not meant to be comprehensive since cats were only opportunistically taken and the site was not visited in every month of the year. Sex ratio of a shot sample of 78 cats in August 1992 consisted of 41 % female, 59% male. Mean body mass ( $\pm$  standard deviation) of this sample was  $4.79 \pm 0.97$  kg ( $n = 46$ ) for males, and  $4.12 \pm 0.73$  kg ( $n = 32$ ) for females. The largest animal taken was a tabby male weighing 8.0 kg. These values are much higher than those reported by Mahon (1999): 3.95 kg (males) and 2.92 kg (females) from a shot sample in the Simpson Desert, but similar to those of Jones and Coman (1982a) who reported an average adult body mass of 4.7kg, from a large sample

throughout Victoria. Mahon did not state when his shot sample was taken, or whether it occurred during an over abundance of food, as was the case in this study.

### 6.1.3.3 Diet

The diet of cats in the area reflects a response to prey availability. When the long-haired rat *Rattus villosissimus* was abundant in 1991-92 the diet consisted almost exclusively of rats. For example, in August 1992, 78 cat stomachs from the study area were examined and 90% contained rats only. A juvenile bilby ear was found in one stomach (R. Palmer and P. McRae unpublished).

When rat populations decreased, alternative prey items were selected, cats then included in their diet a range of native vertebrate and invertebrate taxa including bilbies (Plate 6.1) and kowaris *Dasyuroides byrnei* (P. McRae unpublished). R. Palmer (unpublished) records that bilbies represented 2.3 % of the cat's diet (from scats and stomach contents) in the mitchell grass plains within Astrebla Downs National Park.

### 6.1.3.4 Feral cat invasion in the winter of 1992

Populations of the long-haired rat periodically increase to plague proportions in parts of arid Australia, following successive periods of above-average rainfall (Finlayson 1939c; Plomley 1972; Carstairs 1974, 1976; Newsome and Corbett 1975; Kowald and Johnston 1992; Dickman *et al.* 1999). Such a plague irrupted during 1991-92 in the study area; the experience of this plague is recounted below.

During a field trip to the study site in June 1992 an inordinate increase in the density of feral cats was observed. Cats were recorded on standard 1 km long walking spotlight transects within six monitored sites, in an incidental manner whilst travelling roads to and from study sites at night, and from regular driving transects that commenced in 1995. A summary of the abundance of cats and rats during the years prior to commencement of the plague, and after rat declines, is presented in Fig 6.2.



**Plate 6.1 Feral cat roosting in a black kite nest, Astrebla Downs National Park 1992.**



**Plate 6.2 Cat stomach contents from Astrebla Downs National Park, May 2004. Contents visible include tail and hindfeet of a juvenile *Macrotis lagotis* and two whole *Sminthopsis crassicaudata*.**

Approximately 800 cats were removed from the study area between June and October 1992 with the assistance of 10 Australian Army personnel, Queensland Parks and Wildlife staff and Queensland University staff. On one occasion 170 cats were shot in a single day. The majority of cats were taken from roosting sites in trees during daylight (Plate 6.2). It was not uncommon to remove six-eight cats from raptor nests in a single tree on one day, and remove a similar number from the same tree the following day.

The invasion of cats that occurred in the study area in 1992 provided an enormous surprise to those who witnessed it and provided a remarkable reminder of the dynamic and seasonally dependent functioning of arid zone systems.

An attempt to explain the events of 1992 was made by Pettigrew (1993). He attributed the invasion of cats to a reduction in dingo numbers in the area, suggesting that up to 50 dingoes may have been removed in early 1992. However, this is not supported by data from the current study, which reveal that only four dingoes were shot within the park between 1990 and 1993 out of a total of 17 seen (P. McRae unpublished data.).

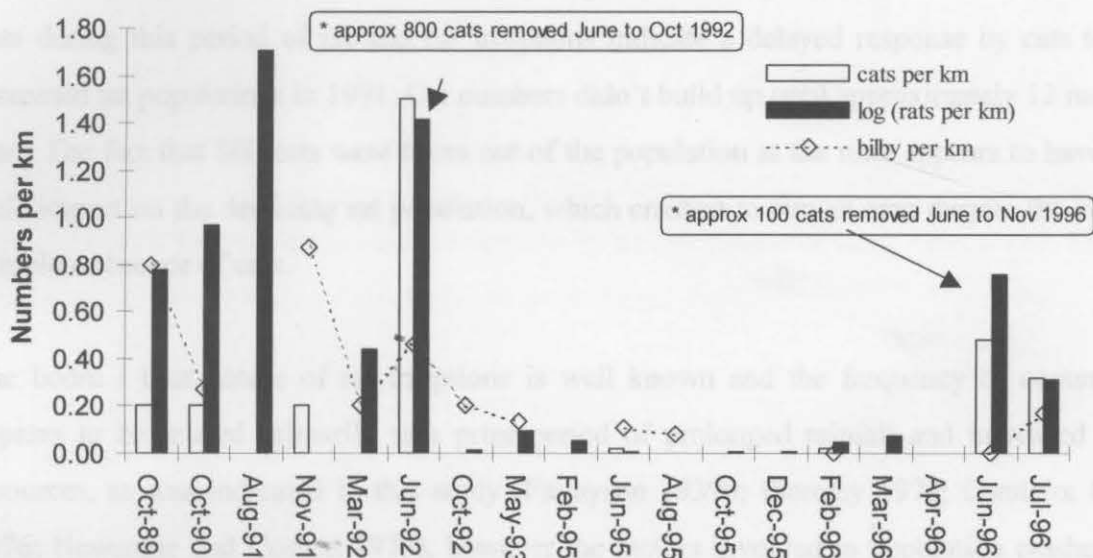
An alternative explanation for what could be considered a normal, however infrequently observed series of events, is presented as follows:

Rat populations increased in the study area from 1989 to reach a peak in August 1991 (Fig 6.2). The health of individual rats at No2 bore on Astrebla Downs NP declined just prior to the population crash in 1991. Rats were observed to be in a poor state of health; were often blind, displaying cannibalism, active long before and after sunset and sunrise respectively, and were observed drinking hot water from a bore drain 10 m from the bore head, where estimated water temperature was above 50<sup>0</sup> C. Rat populations crashed between August 1991 and March 1992, but by August 1992 had reached a similar level as the previous winter. However, by October a similar crash had occurred and populations were back to very low levels. This situation remained for 4 years until a similar response to rainfall, although not as great, resulted in a population peak in the winter of 1996.

The cat population was low during the rat build up between 1989-1992. However, a dramatic increase in the cat population occurred between March and June 1992. This response led to the instigation of an intensive control effort that resulted in 800 cats being taken out of the



population between June and October of that year. Cats also remained at low levels until the rainfall-driven response of rats in 1996 (Figs 6.3, 6.4). Cat populations then increased to just over a third of their 1992 level. This resulted in further cat control that removed an additional 100 cats out of the population.



**Fig 6.2. Relative abundance of cats, rats and bilbies within approx 20 km of No2 bore, Astrebla Downs National Park during the period 1989 - 1996.** (All data obtained by spotlighting transects up to 20 km long)

Indices of bilby abundance 1989-1993 (Fig 6.2) should be treated cautiously, since these data were collected in a more intensive manner, whilst spotlighting on foot at monitored sites of known bilby aggregations, whilst the data from 1995-1996 were obtained from vehicle traverse counts between a different set of sites. The abundance shown between 1989-1993 is thus likely to be over represented.

The predator prey dynamics of this unusual period between 1991 and 1996 have formed part of the Ph.D. thesis of R. Palmer that is nearing completion. His preliminary unpublished data revealed that in May 1994, two years after the rat population crash, bilbies contributed 24% (by volume) to cat diet, rising to a high of 37% in October 1994. By December 1995, bilbies

had disappeared from cat diets, and failed to reappear in the diet during the rat increase of 1996-1997.

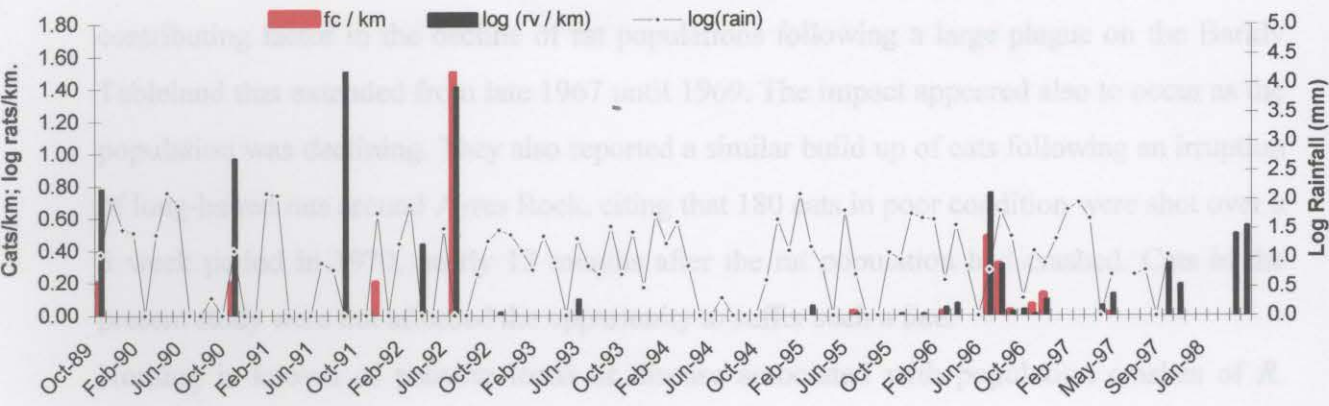
Palmer's data on bilby predation by cats and dingoes during this period will provide an indication of the impact of both species during periods of rat saturation and further indicate any prey switching impacts on bilbies when rat numbers decline. The preliminary data suggest that the cat impact on bilbies could be quite significant in a post-decline environment. The data during this period of rat and cat irruptions indicate a delayed response by cats to the increased rat populations in 1991. Cat numbers didn't build up until approximately 12 months later. The fact that 800 cats were taken out of the population at the time appears to have had little impact on the declining rat population, which crashed to almost zero despite the almost complete absence of cats.

The boom / bust nature of rat irruptions is well known and the frequency of occurrence appears to be related primarily to a prior period of prolonged rainfall and increased food resources, as was indicated in this study (Finlayson 1939b; Plomley 1972; Carstairs 1974, 1976; Newsome and Corbett 1975), however the factors involved in population crashes are not well understood (Predavec and Dickman 1994).

Rainfall for the period leading up to the two rat irruptions in the present study is shown in Figs 6.3 and 6.4. Mean monthly rainfall was above average for the two years prior to the 1991-92 build up, however the reduced rat increase of 1996 was preceded by two years of below average monthly rainfall, 1993 and 1994, and one of above average, 1995 (Fig 6.4).

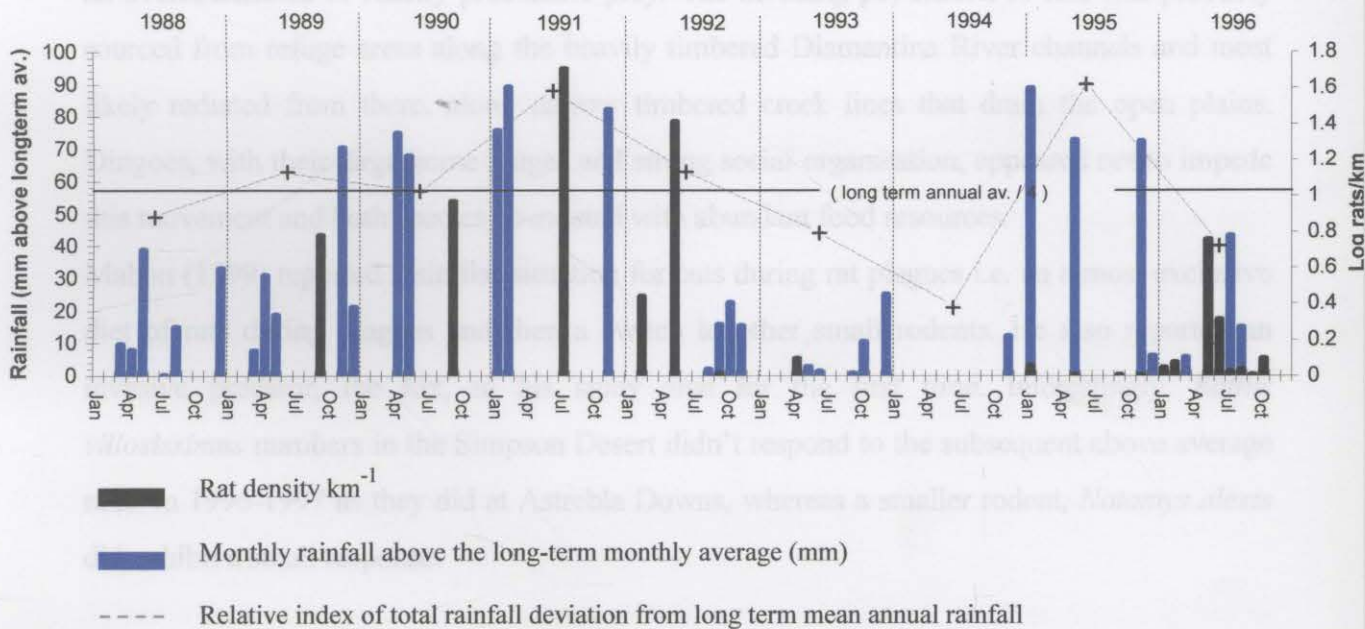
Rat densities were extraordinarily high during the plague periods. Mean densities ( $\pm$  s.e.) obtained from five monitored sites in June 1992 were:  $1273 \pm 440 \text{ km}^{-2}$ ; one site had an estimated density of  $3025 \text{ km}^{-2}$ . (P. McRae unpublished).

Predavec and Dickman (1994) suggested that reproduction as a result of favourable rain, increased food availability, and immigration contributed to the rapid build up. They also noted an increase in predation rates on rats from raptors, foxes and cats whose numbers built up in phase with the rats but found no indication that predation contributed to the decline in rat numbers, suggesting an overall decrease in welfare and hence health of the population, could be a contributing factor.



(*Felis catus* – fc; *Rattus villosissimus* - rv)

**Fig 6.3 Monthly rainfall records during the irruptive phase of long-haired rats and cats between 1991-1996 at Astrebla Downs National Park.**



**Fig 6.4 Annual rainfall deviation from long-term means during the irruptive phase of long-haired rats 1991-1996 at Astrebla Downs National Park.**

Newsome and Corbett (1975) suggested that predation, particularly by dingoes, was a contributing factor in the decline of rat populations following a large plague on the Barkly Tableland that extended from late 1967 until 1969. The impact appeared also to occur as the population was declining. They also reported a similar build up of cats following an irruption of long-haired rats around Ayres Rock, citing that 180 cats in poor condition were shot over a 5 week period in 1970, nearly 12 months after the rat population had crashed. Cats in the present study were not afforded the opportunity to suffer such a fate.

Nothing is known of parasite loads or disease associated with population crashes of *R. villosissimus*, and indeed very little is known about their population dynamics and ecology during non-irruptive periods (Predavec and Dickman 1994).

The events of 1991-1992 indicated that a highly mobile population of cats was able to invade the open, chenopod and mitchell grass plains of Astrebla Downs National Park, in response to an overabundance of readily procurable prey. The invading population of cats was probably sourced from refuge areas along the heavily timbered Diamantina River channels and most likely radiated from there, along narrow timbered creek lines that drain the open plains. Dingoes, with their large home ranges and strong social organisation, appeared not to impede this movement and both species co-existed with abundant food resources.

Mahon (1999) reported a similar situation for cats during rat plagues i.e. an almost exclusive diet of rats during plagues and then a switch to other small rodents. He also reported an invasive predator, the fox, in his study area for the first time. Interestingly, *Rattus villosissimus* numbers in the Simpson Desert didn't respond to the subsequent above average rains in 1996-1997 as they did at Astrebla Downs, whereas a smaller rodent, *Notomys alexis* did exhibit a small response.

Also of interest in Mahon's study was that dasyurids were minimally included in cat diets regardless of the abundance of rats. He attributed this to the preference for dasyurids to hunt in close proximity to spinifex clumps that cats were reluctant to enter, whereas the rodents frequently ranged in open areas (Mahon 1999). Five species of dasyurids were recorded in the

diets of cats in present the study area, occurring as 5% (vol) in scats (R. Palmer unpublished). This showed that dasyurids in the open plains are susceptible to cat predation. Clearly the dynamics of the interaction of the three predators in response to competition and prey selection are not well understood.

In the present study, dingo numbers did not show a similar response to the cats (personal observation). This could be related to the large home ranges, and more stable social structure of dingoes. It could be that the highly mobile cats simply invaded the area, whereas the resident dingoes responded more slowly to the improved conditions with increased reproductive output. Some support for this is evidenced by the quite dramatic increase in encounter rates of dingoes in the secondary irruption of rats in 1996-1997 (personal observations).

The large home ranges of dingoes would also be likely to reduce the spotlight encounter rates of them.

The impact on bilbies as a result of this type of irruptive event appears to be minimal during the irruptive phase, but may be significant in the declining phase when cats are forced to seek alternative prey. Mahon (1999) found that cats and foxes remained abundant for at least a year after the rodent crashes in the Simpson Desert, and cats particularly, continued to prey on the remaining low-density animals.

#### *6.1.3.5 Potential Impact of feral cats - an hypothetical scenario.*

The theoretical impacts of cats on prey species can be ascertained by estimating required food intake, based on energy requirements, and prey selectivity in different environments (Table 6.1).

Whilst this is an hypothetical scenario it demonstrates a 'What if' situation which is real in terms of: i) observed cat numbers in the area; ii) rat population dynamics and iii) the clumped distribution and low density of bilbies.

An average sized cat of 4 kg needs to consume approximately 300 g of flesh/day (Paton 1993). Cats also prefer a prey size less than 200 g (Dickman 1996a). Arid zone cats have been

shown to prefer rats when they are abundantly available (Mahon 1999; R. Palmer unpublished, Dickman 1996a, 1996b, Dickman *et al.* 1999). These fit within the preferred prey size range of cats, with an average mass of 134 g (Strahan 1998).

Juvenile bilbies fit well within this mass range also. In this study the youngest independent individuals captured weighed 130g (female) and 135g (male). These were newly weaned, independent juveniles that were naïve and vulnerable. So much so, that a 50 year old, non-feline, non-canine and supposedly advanced primate author, could capture them by hand at night.

Plate 6.1 provides a clear example that feral cats do take bilbies (see also Paltridge 2003; Southgate and Possingham 1995; R. Palmer unpublished) and if as an example, one quarter of a population of 200 cats were to take one bilby per week, the impact from table 6.1

**Table 6.1 Theoretical impact of cats preying on bilbies over a range of periods, based on cat energetic requirements.**

Number of cats	number of adult or juvenile bilbies taken (based on 'bilby equivalents'*)							
	1 Day		1 Week		1 Month		2 Months	
	adult	juvenile	adult	juvenile	adult	juvenile	adult	juvenile
1	0.05	0.2	0.4	2	2	6	3	12
50	2.7	10.7	19	75	75	300	<b>150</b>	<b>600</b>
200	11	43	75	300	300	1200	600	2400
400	21	86	150	600	600	2400	1200	4800

\* 'bilby equivalent' calculated as the minimum energetic requirements of 300 g of flesh per day for an average 4 kg cat (see Paton 1993). Average adult bilby 800 g, juvenile, 200 g.

could theoretically be 150 adult bilbies or 600 juveniles in a 2 month period. This obviously is entirely hypothetical, but is useful in identifying the potential impact.

In real terms this scenario is unlikely to occur given that bilby distribution is spread patchily across the park and many areas are well away from timbered drainage lines and permanent water, the areas where cat concentrations are most likely to occur. It does mean that bilby populations in the vicinity of permanent water and wooded drainage lines could very easily become locally extinct. If these areas are periodically required as refuge areas for bilbies and are occupied by cats, then total extinction is conceivable over time. Smith and Quinn (1996) termed these 'hyper-predation' events.

To summarise, rat plagues can result in a build up of cat populations. These populations can be large, as evidenced during 1991-92. Whilst rats almost exclusively satisfy cat diet during these times, a critical period is reached when the rats decline. Rat decline can literally occur overnight and can be dramatic. Cats switch prey and potentially are likely to have an enormous impact on bilby populations at these times.

## **6.2 A COMMON ELEMENT - WATER ?**

Water is delivered to the broad study area naturally through local rainfall, and by infrequent flooding events that result from monsoonal rainfall in river catchments well to the north of the study area (see Chapter 1). In addition to natural water, increasing water has been provided to the area by tapping supplies of water contained in the sedimentary layers of the Great Artesian Basin. This has occurred as a result of demands from the grazing industry to sustain cattle, and to a lesser extent sheep, on the large areas of native pastures that are arid-adapted to survive the long dry periods.

The first bores in the area were put down in the late 1800s. The main artesian aquifer is the cretaceous Longsight Sandstone Formation, which supplies both artesian and sub-artesian water (Wilson *et al.* 1990).

### *Positive impacts*

There are not many. However, one recent positive water conservation outcome has been the State Government's program to cap free flowing bores of the Great Artesian Basin. This has

meant that water previously flowing into many bore drains (up to 20-30 km in length) has ceased and the losses to evaporation and seepage have been dramatically reduced.

Whilst this is a positive water conservation outcome, I suggest that it is a negative ecological outcome for an area that has developed a suite of plants and animals that have evolved to deal with the absence of water, exotic predators and extended grazing during dry periods.

### *Negative impacts*

The provision of artificial water provided benefits to all three predators fox, dingo and cat. Rainfall drives ecological systems in the arid zone, and water in some form, is critical to the survival of most mammals (Stafford Smith and Morton 1989). Dingoes and foxes require free water (Corbett 1995, Saunders *et al.* 1995) whereas cats appear not to (Newsome 1991; C. Dickman pers. comm.), although are likely to benefit from it. Bilbies also don't require free water (Gibson *et al.* 2002).

When seasons are good most species of plants and animals flourish. In these times predators have access to abundant, more readily procurable alternative prey including rodents, reptiles and breeding birds, which can result in an increase in predator populations. The nature of prey population increases, especially some of the highly irruptive rodents like *Rattus villosissimus*, is that they can crash dramatically, leaving behind large numbers of hungry predators. These are critical times for bilbies and other native species in the weight range preferred by cats, dingoes or foxes.

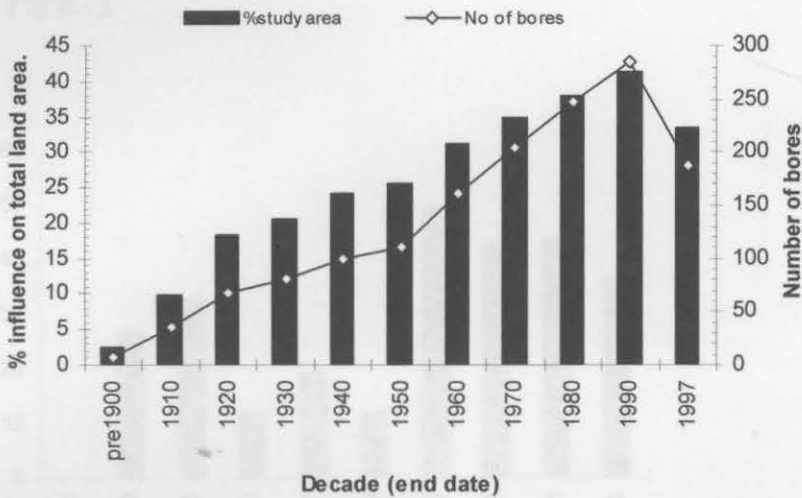
#### **6.2.1 Spatial distribution of artificial waters in the study area**

The study area is naturally dry, evaporation rates are high and mean annual rainfall is approximately 200 mm throughout the area (see 1.4.2).

Grazing is dependent on intermittent flood events which, given the low relief of the area, result in massive flood plains existing in many areas along the Diamantina and Georgina rivers. These flood events provide water that results in excellent grazing opportunities for livestock even though the country may be in drought.



To improve the temporal grazing opportunities for livestock artificial waters were first introduced into the area in the late 1800s (Wilson *et al.* 1990). Some were designed to provide water for towns and homesteads, however most were established for stock usage after all natural water holes had dried up. Native pastures of the area provided adequate food for stock but distances to water limited the area that could be grazed. Since then there has been a steady increase in the number of artesian bores added each decade. (Figs 6.5, 6.6).



**Fig 6.5 The expansion of artificial watering points in the study area this century.**

(% influence on the axis is based on a 10 km radius from all bores in the study area.)

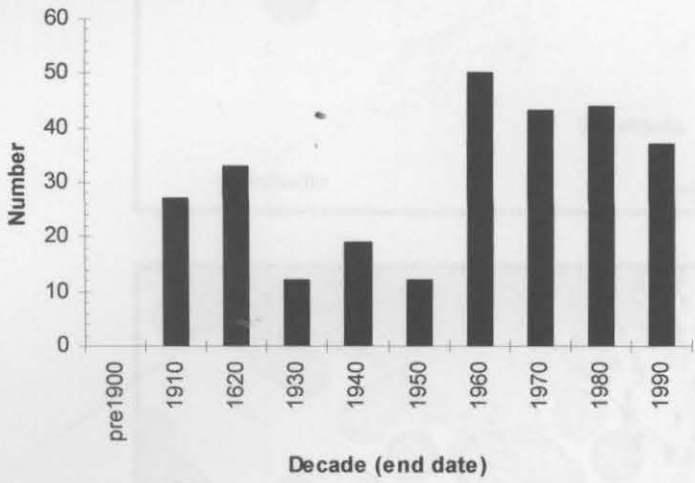
Two periods of rapid expansion can be recognised: 1910-1920 and 1950-1960 (Fig. 6.6). This is probably related to the long drought in the early 1900s that forced many from the area (Wilson *et al.* 1990), and in the 1950s, possibly increased post war development and advancements in drilling technology. The reason for the decline between 1990-1997 in Fig 6.5 is unknown, however it may be related to the increased costs involved in drilling new bores.

Fig 6.5 shows that in 1997 approximately 40% of the total study area was within 10 km of an artesian bore with permanent flowing water.

Many earth tanks and dams have also been added to the landscape and in the case of dams, the water collected results from natural rainfall. The fact that it is collected and stored is

unnatural and thus contributes to the artificial water load in the arid landscape. These serve to prolong the effects of rainfall events in supplying drinking water for species that require it.

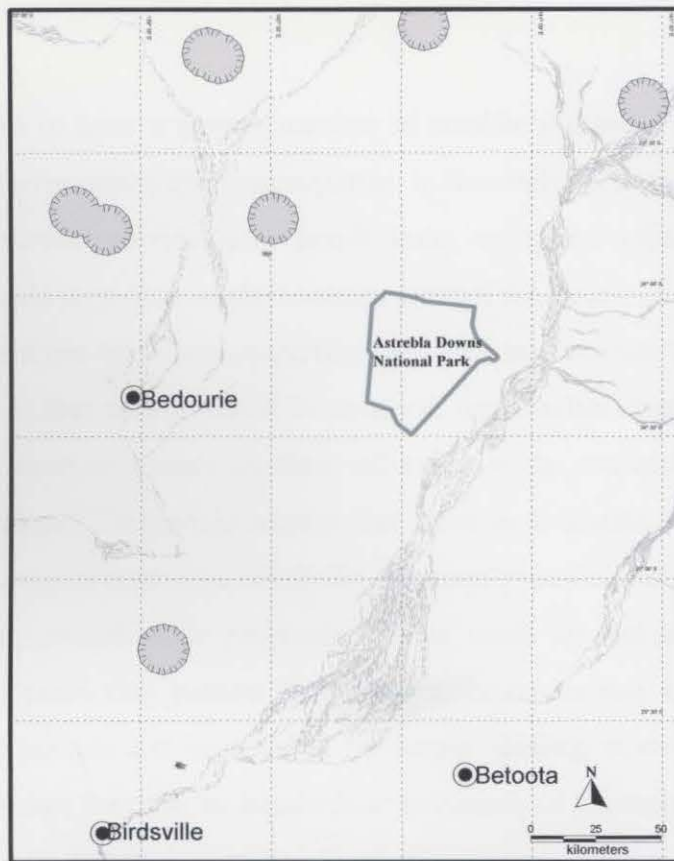
In order to quantify the extent of these additional water sources, the location of earth tanks and dams were digitised from the latest editions (mostly 2002) of the 1:25000 topographic map sheets produced by NATMAP (Geoscience Australia 2003). These were then imported into a GIS layer to show the spatial geometry of the expansion of artificial water between 1900-1997 ( Fig 6.7).



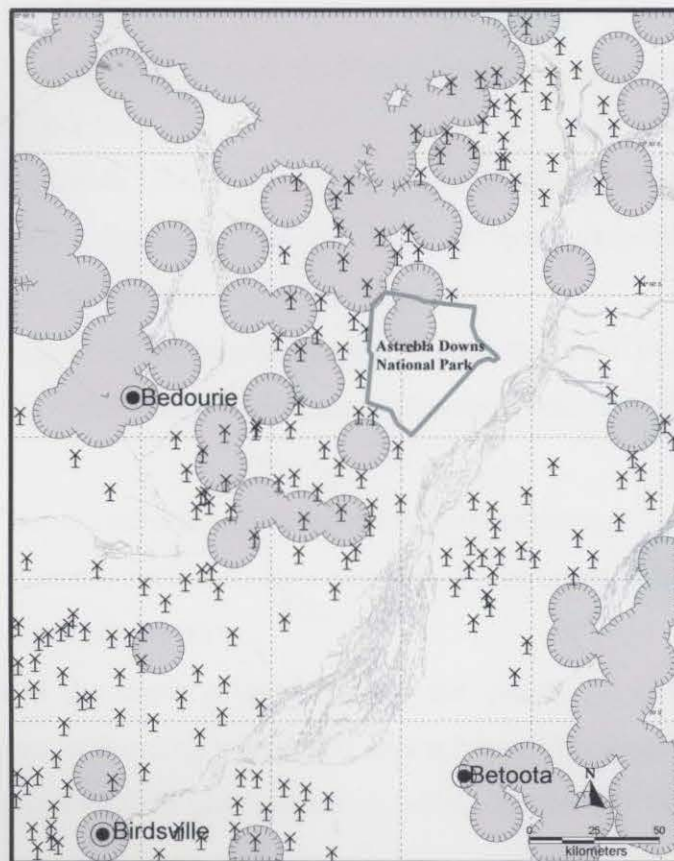
**Fig 6.6 The number of additional (new) bores each decade.**  
 (Note: 8 bores were in existence at the turn of the century)

A suggested basis for the present spatial distribution of artificial waters is provided as follows:

1. Location of bores – determined by property management decisions. The distribution of bores is intrinsically related to property management decisions and based on the livestock carrying capacity of each paddock and the presence/absence of naturally occurring water. The observed aggregation of bores in the northern part of the study area (Figs 6.7, 6.8) is probably related to changes in land use such as a greater emphasis on sheep grazing. Sheep grazing enterprises are generally smaller in area, require more intensive management



1900



1997



10 km radius around artesian bores.



earth tanks and dams.

**Fig 6.7. Distribution of artesian bores 1900 and 1997, and earth tanks and dams 2002.**

( Note : no data for dams /earth tanks 1900 ).

and as a result tend to have a greater number of smaller paddocks to facilitate effective management. Moreover, sheep grazing properties in the study area tend to be owned/leased and operated by private individuals or family units, compared with a preponderance of company-owned cattle properties in the southern parts of the area.

Economic considerations on sheep properties may well account for the greater density of sub artesian bores in that area. It could be assumed that smaller single income operations would necessarily result in a more constant utilisation of the available plant resources for economic reasons alone. This would require that water be available at the cheapest cost in all paddocks. Sub artesian bores and windmills or pumps provide a solution in this case.

The larger company-owned cattle properties further south are not so reliant on climatic conditions (rainfall promoting pasture growth) to maintain income at the company scale. Prolonged drought periods can be endured by simply shifting stock to another company property in a wetter area that may be hundreds or thousands of kilometres distant.

Bores are not the only sources of artificially supplied water. Artificial ponding of natural waters from rainfall and runoff frequently occurs in the form of earth tanks and dams. Most of these are additional to those shown on Figs 6.7 and 6.8 and were not shown on the topographic map sheets.

It is difficult to estimate the full extent of these additional water sources, however as an indication, the following example from two large company properties in the study area provides some idea of their extent:

Property 1: 14 flowing bores and approximately 30 earth tanks and de-silted waterholes.

Property 2: 2 flowing bores and 31 earth tanks and waterholes.

## 2. Location of bores – determined by landscape geomorphology.

In addition to management decisions, consideration is also taken of landscape geology and the limiting factors associated with it.

Regional variation in the depth of aquifers and the quality of water they provide is a primary consideration in deciding whether to drill a bore. Also, regardless of management intent, some landscapes by their physical nature, either do not lend themselves to livestock

grazing and/or the sinking of bores, or require artificial water, due to their proximity to natural watercourses or waterholes. For example:

i) The extensive anastomosing network of channels in the major drainage systems of the Diamantina and Georgina rivers and Farrah's creek are largely free of bore facilities. Many of these extensive areas become periodically inundated as a result of flooding rains in catchment areas to the north. These floods inundate large areas within the channel network and adjacent flood plains, and not only provide a prolonged period of growth for plants, but also sustain perennial and ephemeral waterholes. These areas as a result are natural providers of the necessary elements to grow livestock without the added costs of having to provide artificial waters.

ii) Some areas are simply not suitable for grazing as a result of soil physical properties and/or low rainfall. For example, clay pans that are devoid of vegetation such as the large Bilpa Morea claypan between Birdsville and Bedourie; residual stony hills; extensive dune systems supporting predominantly unpalatable grasses for livestock (see landzone coverage, Fig 1.2) and the vast gravel and gibber plains which support very little vegetation cover (see stony plains land zones west of the Diamantina river in the south central part of the study area, Fig 1.2.)

### **6.2.2 The ecological impact of artificial watering points.**

Vegetation in the study area is dominated by drought evading species that complete their life cycle in a brief period of high soil moisture and survive dry periods with dormant seeds. Ephemeral species constitute 55% of the total species and many such as *Iseilema* spp., *Dactyloctenium radulans* and *Aribidella nasturtium* are able to set seed when only a few centimeters tall (Purdie 1990).

Grazing by domestic livestock is likely to produce seasonally variable impacts on the vegetation. As early as 1936 Blake commented on the deterioration of native pastures in the following manner:

*“The grazing lands of Queensland are one of the State’s greatest assets, and on their condition depends to a great extent the prosperity of this country. In many districts, unfortunately, these lands have deteriorated very considerably.*

*The deterioration is brought about either by the more or less complete disappearance of edible plants or by replacement of palatable species by unpalatable species”.*

Biologist, Francis Ratcliffe visited Australia in 1935 and travelled the inland from South Australia, through Birdsville, and into Queensland, to study the impacts of erosion. In 1938 he reported his impressions of water in the landscape:

*“It is not as though the land were a desert: it must have been far otherwise when the white man first saw the country in its unravished state. It is merely waterless. I think there can be no doubt that it was never permanently inhabited by the aboriginals; and probably the greater part of the animal life moved into it only when the flush of feed was on. The coming of the whiteman was therefore a great boon to the wild creatures, for in providing water for his stock he unintentionally benefited the kangaroos and emus, the parrots and cockatoos, and all the other creatures which before his coming had only been able to make these regions a temporary home, but now were able to live there permanently*

*In other parts of the inland pastoral country bores and wells are the fashion. Here the land is dotted with dams (tanks, as they call them in New South Wales), which are nothing but artificial ponds dug out by horse- or bullock- drawn scoops. Some of them are 100 yards square and nearly thirty feet deep, and are haunted by seagulls! My host told me he had calculated that the sheep only drank one-seventh of the water which ran into his dams; the rest was licked up by the thirsty sun”.*

He further commented on the development of inland Australia:

*“The conquest of the Australian inland demanded fortitude and endurance, self reliance and faith; nor did the need for these qualities disappear when the conquest had been achieved... Australians have every reason to be intensely proud of their record in settling*

*the great spaces of the inland. They are to be blamed only in the way they seemed to have done the job too thoroughly”.*

Grazing impacts have been reported by many authors (see Blake 1936; Leigh and Mulham 1965; Costin and Frith 1971; Roberts 1972; Denny 1982; Orr 1986; Morton 1990; Landsberg *et al.* 1997; Ludwig *et al.* 1997; Johnson 1999.)

In the arid zone at least, where grazing historically was only possible within proximity to natural waters, the provision of additional waters must be blamed for many of the grazing impacts reported.

Ludwig *et al.* (1997), when referring to dysfunctional landscapes, reported a loss of conservative landscape function, and attributed this primarily to the loss of perennial ground cover and decrease in small-scale patchiness. Decreased patchiness, especially the loss of refugia, has been suggested as a major contributor to losses of small mammal assemblages in arid Australia (Morton 1990).

Very few studies exist that explore the impact of grazing on terrestrial invertebrates (Landsberg *et al.* 1997). These authors suggest however that at the very least, species abundance, composition and richness could be expected to respond seasonally to changes in vegetation structure and composition. They defined ‘increaser’ and ‘decreaser’ species as those whose abundance increased or decreased respectively, as a result of proximity to artificial water sources.

Across all gradients they sampled in the arid zone, the following decreaser species responses were observed: 15% of overstorey plants; 22% of reptiles; 23% of seed bank plants; 23% of birds; 23% of ants; and 38% of understorey plants. They pointed out that the relationship was log linear i.e. abundance dropped logarithmically with proximity to water and converse.

They also reported that an average of around 75% of all species appeared not to be disadvantaged by proximity to water. They further suggested however, that the greatest conservation concern was related to the fact that potential habitat for the remaining 25% of taxa (decreaser species response), had been reduced to perhaps 3-8% of its original extent as a result of the proliferation of artificial water points, and that water points were so widespread

that most of the chenopod and acacia rangelands were currently within 10 km of a water source. Most of these biological diversity impacts associated with water points, are likely to impact in some way on the ability of bilbies to satisfy their dietary requirements, especially those reported for soil seed loads, understorey plants and ants.

There are few literature accounts of the impacts of below-ground invertebrates, however Landsberg *et al.* (1997) suggested that grazing may affect ants and termites, by removing food supplies such as grass and seeds. However, in a study in the western Australian wheatbelt, grazing by sheep was reported to have no general effect on termite abundance or species composition (Abensperg-Traun 1992). Grazing by domestic livestock however, has been shown to reduce below ground plant biomass (Schuster 1964) and alter the quality and quantity of food available to below ground herbivores by increasing nitrogen concentration in plant tissues (Seastedt *et al.* 1988). Milton and Dean (1992) also reported that cicadas with a long lived subterranean phase in life cycle, decreased in density in response to grazing, where long lived perennials were replaced by ephemeral and short lived species.

I suggest that the role of termites in landscape functioning and particularly bilby ecology is critical in the current study area. Termites feed on sound and decayed wood, grass, fungi and other material of vegetable origin such as dead leaves, bark, humus and herbivore dung (Gay 1970) and have been shown to an important part of bilby diet (Southgate 1990c; Gibson 2001).

Termites provide an invaluable food resource in that they can survive drought periods by utilising dead plant material, which they store in subterranean chambers (personal observations). The ecology and role of termites in this arid system is in need of further investigation, and could be critical in understanding the persistence of bilbies in the area. This is possibly particularly so through extended droughts when termites are able to survive on dead plant material alone.

In concluding, it is apparent that the addition of water for grazing purposes, in this arid landscape, is likely to have had adverse impacts on plant and invertebrate species diversity. This is likely to have a flow on impact to those native species such as the bilby that rely on invertebrates and seeds, and may also have had an impact in the historical declines of a range



of other species. Given the nature of the landscape and the infrequent rainfall in the current study area, it is likely that this impact has been minimal and restricted to the grazing range of stock out from water, since regardless of how much water is available, livestock must have pastures on which to feed.

During droughts stock simply have to be removed and further, unlike grazing enterprises in more mesic areas further east, drought relief feeding of hay can't be used to carry from 6 000 – 20 000, 800 kg bullocks through a 2 to 3 year drought.

These systems can thus be seen as fairly resilient in the short term since overgrazing is less likely to push plant systems to their ecological limits. The long-term impacts of grazing, however, may reveal a slow process of degradation, as a result of slow decreases in plant species diversity, losses to the soil seed banks and a decrease in invertebrate species diversity.

The impact of increased water points has, conversely, had a major impact on mammalian 'increaser' species such as red and grey kangaroos that have benefited as a result of reliable water resources. Of particular interest in the current study is the impact of increased water on the exotic predators known to exist in the area.

The major potential predators of bilbies in the area are the dingo, the introduced European red fox and the feral cat, and all have been discussed above.

Whilst no data exist on the abundance of each of these species in relation to water in the area, there is sufficient ecological and biological data that suggest each will benefit with access to reliable water. "*In hot arid areas the distribution of water is clearly the single most important factor that determines where dingoes and their prey can be found, but food resources will ultimately dictate how long a pack of dingoes can forage in any single locality*". (Corbett 1995).

Artificial waters advantage dingoes and foxes since both need to drink regularly during hot weather. Cats also, are likely to benefit since it would allow them to exist on prey containing lower water content.

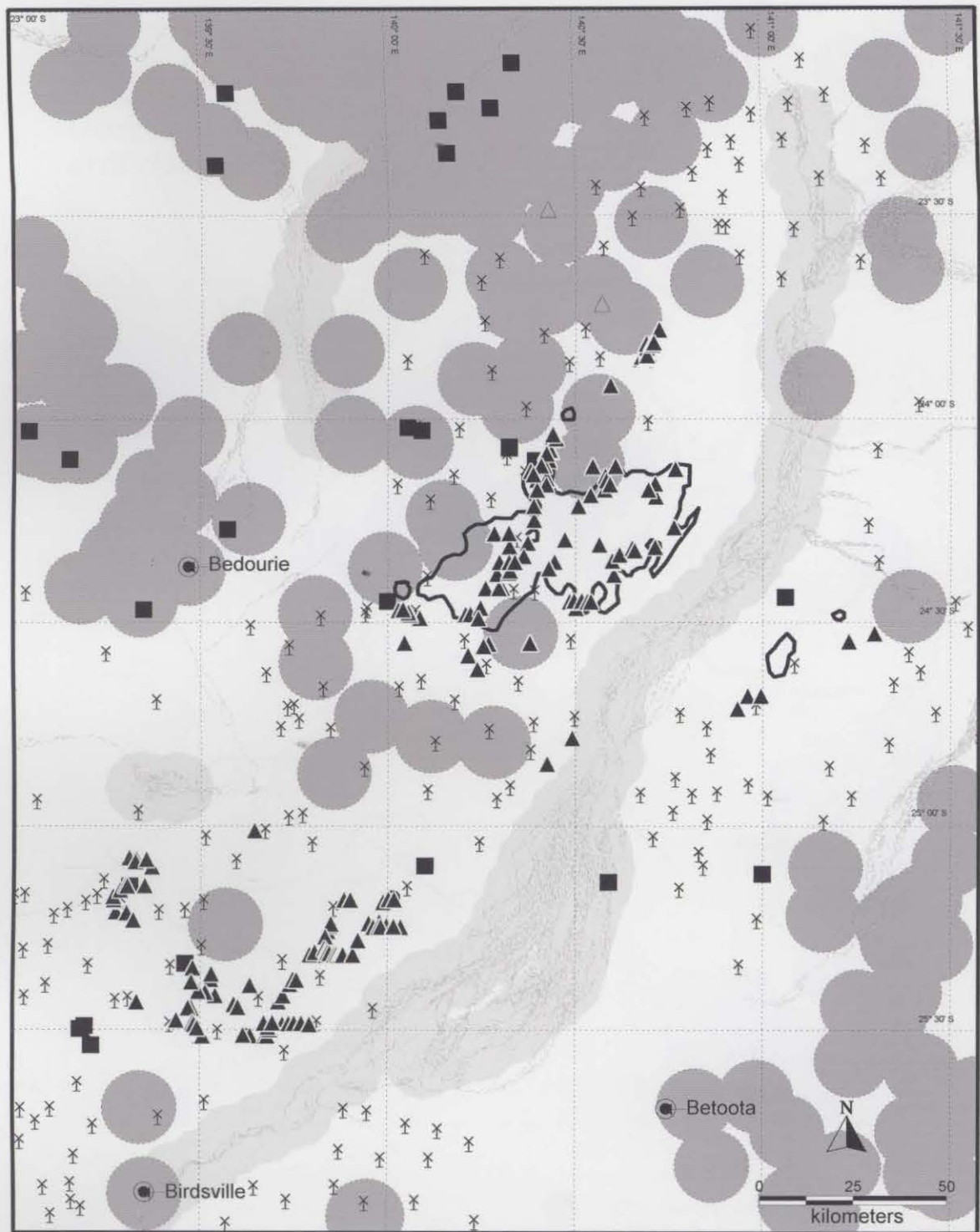
Earth tanks and dams are likely to also spread the natural influence of rainfall events to areas far removed from natural waterholes and thus increase the prey habitats that predators can access.

It appears the distribution of bilbies within the study area has contracted to areas of suitable habitat (suitable soils to burrow in and adequate food resources) where it is suggested that predator impact is minimal. These areas are outside the suggested artificially inflated predator populations that benefit from water. There are currently no data to support this suggestion, but I present an overlay of current active bilby records in the study area with the distribution of natural and artificial water sources in Fig 6.8. The map convincingly reveals the spatial separation of bilbies and areas influenced by artificial waters.

There may be complex ecological interactions between all three predators, invertebrate diversity and grazing, however I think the map alone tells a sufficiently good or bad story.

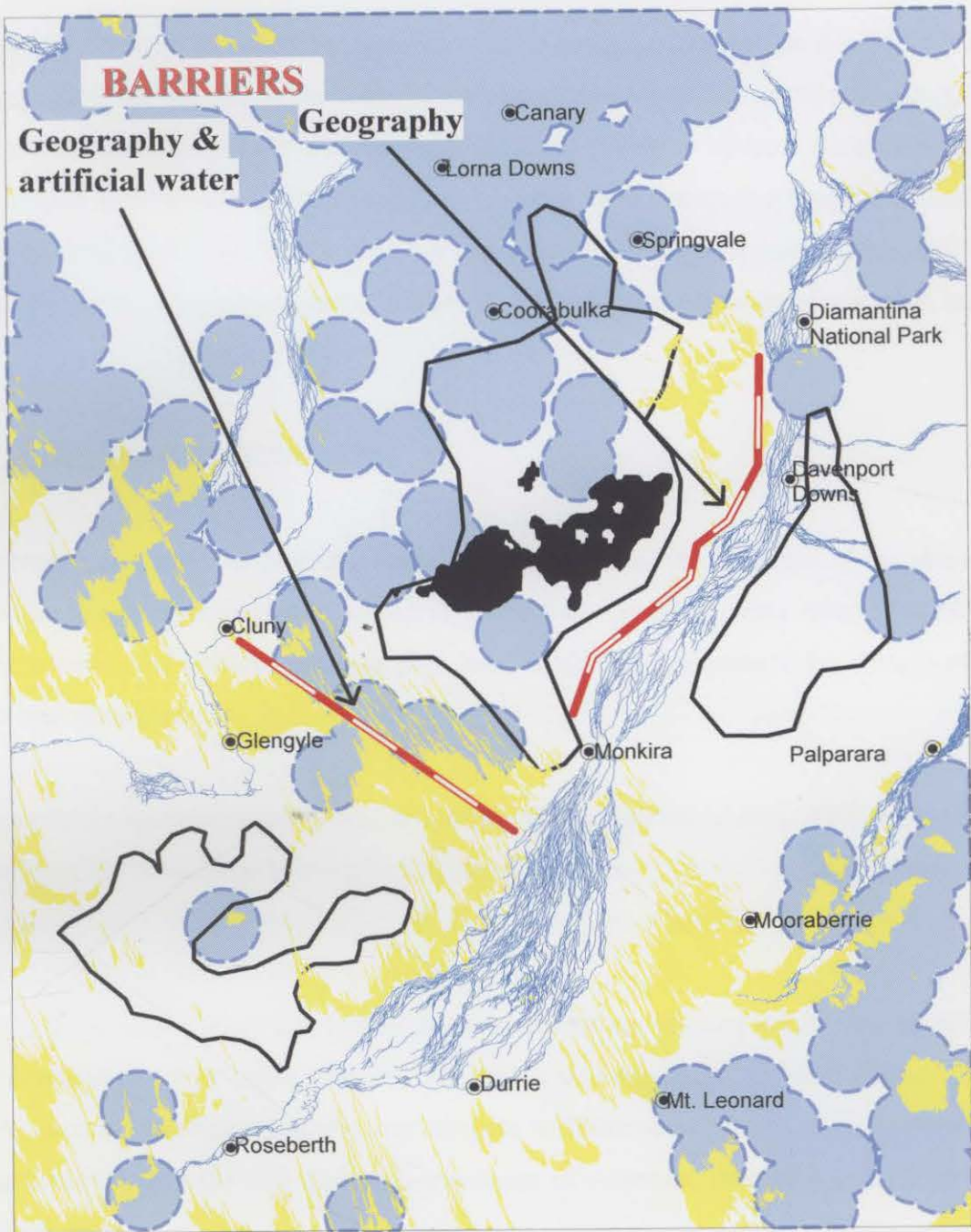
The current distribution of bilbies in Queensland consists of core populations persisting within Astrebla Downs National Park and the ashy plains of Coorabulka and two sub-populations that are geographically isolated from the core areas. (see 5.1.1). The eastern population was mentioned as being geographically isolated by the Diamantina River. However, the Birdsville population, in addition to the physical barrier consisting of dunefields and claypans, is potentially additionally isolated by the occurrence an artificial water barrier, which is likely to further inhibit interchange/exchange of animals and heterogeneity between the two populations (see Fig 6.9).

To survive in these areas any species needs to be able to go without free water (or at least be able to travel big distances to it) and be able to utilise food sources available in drought times. The currently preferred habitat of the bilby in the area is the ashy, cracking clay plains (F1 landsystem). These areas often referred to by the locals as 'dead heart country', and are generally unsuitable for grazing, since the soils are so deep and friable that they require substantial rain to elicit both short-term annual, and longer-term perennial plant responses. As a result most of the time the ground is devoid of living vegetation. The



- 10 km buffer around artesian flowing bores
  - 10 km buffer around the major rivers in the area.
  - earth tanks and dams
- active and recently active bilby burrows - 1999
  - historical records of bilbies prior to 1985
  - core burrow area from 1999 air surveys.

**Fig 6.8 Distribution of water and active bilby burrows in the study area 1999.**



Distribution 1994.



Core burrow areas 1999.



10 km radius around artesian bores in the area 1997.



Dunefield landzones in the study area.

**Fig 6.9 Core burrow areas 1994 and 1999 and suggested geographical barriers that could isolate the three extant populations of bilbies currently present in the study area.**

ephemeral response to rain is generally short lived and not of a great use to cattle as a result. I suggest it is for this reason the areas haven't been 'developed' with artificial waters.

The omnivorous bilby is not a dietary specialist and is able to utilise a wide range of plant and animal food resources at metabolic levels that are less demanding than for the eutherian carnivores (Gibson *et al.* 2002). This has resulted in the bilby persisting in areas such as the ashy clay plains, where the impact of grazing is reduced and predator density is much lower.

### **6.3 SUMMARY DISCUSSION**

The provision of artificial water has ecologically transformed the landscape of this arid region. It can no longer be ecologically defined as an 'arid environment', since many of the impacts of the provision of artificial water supplies have resulted in disruption to the ecology of many plant and animal species.

It is a pity the hydrologists or geologists naming the main water bearing sedimentary deposits in the area (the cretaceous 'Longsight Sandstone Formation', see 6.2) were 'short sighted', or perhaps unaware of the ecological impacts artificial water would bring to the ecology of the area.

Whilst State and Federal governments are contributing millions of dollars to subsidise admirable water conservation schemes, their efforts also appear a little 'short sighted' in some ways, since the ecological impacts may compete with the water conservation outcomes. This is particularly so in the arid and semi-arid zones of Australia, that historically didn't have artificial water.

How we can ameliorate this situation, and hopefully restore at least some form of 'natural?' 'ecological aridity' to these areas, is one factor of management and conservation discussed in the concluding chapter of this thesis.



# CHAPTER 7

## *GENERAL DISCUSSION: CONSERVATION AND MANAGEMENT*

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### 7.0 INTRODUCTION

The study has described many previously unreported aspects of natural history and ecology of the bilby *Macrotis lagotis* from a wild population. The bilby is an unique species in the arid zone of western Queensland in that it is not, a physiologically, classically adapted arid zone specialist, but it does possess a suite of physiological, biological and behavioural attributes that have enabled it to survive in the arid zone, in what could be regarded as marginal habitat compared to areas it formerly occupied in more mesic areas of the continent. The bilby's field metabolic rate is not significantly different from bandicoots in more mesic areas however, the above characteristics combined with its omnivorous diet and low water requirements, has allowed it to satisfy its nutritional requirements in these marginal arid environments (Gibson *et al.* 2002).

In desert environments where there are extremes of temperature, wide thermal fluctuations and infrequent and low rainfall, it is critical for animals to be able to conserve water and regulate body temperature (Costa 1995). Burrows provide a mesic microenvironment, which serves to dampen the large daily fluctuations in temperature and relative humidity (Degen 1997).

The use of deep burrows by the bilby, combined with its nutritional ecology, is likely to be a key factor that has allowed the species to occupy this harsh environment. In addition, the diurnal use of burrows confers protection from the range of diurnal predators in the area,

including reptiles and raptors. Bilbies are vulnerable to predators in the channel country landscape because of the flat and open habitat, however the clumped nature of burrow aggregations and use of multiple burrows by individuals, is likely to reduce (perhaps minimally) the chances of predation, by increasing the number of escape options for bilbies and increasing the digging effort required by predators. The ability of the bilby to survive extended droughts is also probably critical in reducing the impacts of exotic predators that require free water, and possibly provides an opportunity for bilbies to recruit to their populations at a time when juvenile mortality, as a result of predation, is likely to be reduced.

The fact that bilby burrows are deep and very apparent in the open landscapes enabled the distribution of the species to be determined using aerial survey techniques. Whilst these techniques are inherently 'sloppy', they perhaps provide the only useful method of monitoring changes in burrow density, and hence bilby population size through time, at a broad scale and in a cost effective manner (See Chapter 4.).

The use of burrows by the species has enabled broadscale estimates to be made of population extent of the species using aerial survey techniques based on burrow counts. An understanding of the use of burrows by bilbies was used in Chapters 3 and 4 to investigate the broad scale distribution of the species in Queensland. This has revealed a disturbing continuing decline, which presents an urgent conservation message to land managers.

## **7.1 THREATS TO BILBY POPULATIONS**

The bilby has suffered a massive historical range decline (99%) in Queensland since European settlement (Chapter 5). This was attributed to habitat alteration including, primarily, the introduction of exotic predators and competitors. Range decline was observed to be continuing in the areas currently occupied by bilbies, following broadscale surveys conducted in 1994 and 1999 (Chapter 4). Whilst the bilby population was estimated to double between the two survey periods, the core burrow area contracted to two localities centred on the ashy

plains of Astrebla Downs National Park and the neighbouring property of Coorabulka. The population of *M. lagotis* in Queensland is considered to be dangerously low.

Fluctuations in the populations of arid zone species can result in large temporal changes in abundance as a result of increased rainfall. This was highlighted in Chapter 6 where the irruptions of *Rattus villosissimus* followed extended periods of above average monthly rainfall. These rainfall-enhanced conditions resulted in a massive increase of abundance of native plant and animal species. Included in this biological 'boom' period was an extraordinarily large population of feral cats, which were shown to present serious threats to bilby populations during the declining phase of the rat irruption. It was suggested that these highly mobile cats dispersed along timbered drainage lines from areas along the Diamantina River, which are probably a significant refuge area for them during dry times.

The major threats to extant populations of the species in Queensland, I suggest, are inextricably linked to predation (see Chapter 6). The predator link is complex and involves:

- i) The long term and permanent residency of the dingo;
- ii) Infrequent incursions of the feral cat (associated with plagues of the long-haired rat);
- iii) Absence of the red fox; and
- iv) The addition of artificial water sources to the area.

The impact of water is suggested to be the major indirect threat to the long-term survival of the bilby in Queensland. Water in its natural form is applied to the channel country in two ways: natural local rainfall, which is low and sporadic; and water from flood events that result from monsoonal storm events that occur well to the north of the study area. These two infrequent natural rainfall events produce lush conditions in local areas where populations of plants and animals flourish, as was experienced in the study area in 1991-1992. These times also provide ideal conditions for grazing by domestic livestock.

In addition to the natural watering referred to above, water has been introduced to the landscape by tapping into supplies from the Great Artesian Basin. This addition of 'artificial' water has added another dimension to the ecological impacts on native species in the area.



These additional watering points have allowed graziers to extend the grazing periods of livestock to well after the wet periods and also increase the areas utilised within individual paddocks. The impact of this grazing on plant and invertebrate species diversity has been reported to result in the favouring of 'increaser' species, and a subsequent loss of biological diversity (Landsberg *et al.* 1997). Landsberg *et al.* (1997) further pointed out, however, that the greatest conservation concern was related to the fact that potential habitat for the remaining 25% of taxa ('decreaser' species) has been reduced to perhaps 3-8% of its original extent, as a result of the proliferation of artificial water points, and that water points are so widespread that most of the chenopod and acacia rangelands now lie within 10 km of a water source. Purdie (1990) reported that grazing by sheep and cattle in the region had undoubtedly induced subtle changes to plant species composition and structure, but added that some effects were noticeable such as the replacement of *Astrebla* spp. tussock grasslands by induced herblands around watering points.

The long-term impacts of grazing associated with artificial water points in the study area are unknown, however it is suggested a general lowering of land condition could result. Plant recruitment and survival are the two factors involved in vegetation fluxes in any plant community. Orr (1986) suggested that the major impact of rainfall on botanical composition in mitchell grass plains is related to be the ability of perennial grasses, particularly *Astrebla* species, to compete for soil moisture, and that the relative abundance and basal cover of perennial grasses is determined by recent rainfall history of 1-3 years, while relative abundance of annual grasses and forbs is influenced by immediate past rainfall. He concluded by suggesting that rainfall is the overriding factor that directly influences the recruitment and survival of plants and also the extent to which grazing removes biomass from the pasture (Orr 1986). These plant responses to infrequent rainfall events are likely to alter plant species diversity and soil seed loads over long periods of time under a continuous grazing regime. The implications of plant and grazing dynamics are obviously dependent on the management strategies of individual property owners in the area. Some owners graze their stock well past the point of the pasture's abilities to recover, whilst others are more careful with their pasture

conservation and shift stock off earlier. However, a point is still reached where, regardless of how much additional water is available, if there is no pasture, stock must be moved off.

It is unknown if the decline in bilby core areas observed in 1994-1999 was a result of 'normal' arid zone temporal fluctuations, or a real decline. I suggest that this decline was primarily related to predation from exotic predators, which were able to persist in the landscape for longer periods following a rainfall 'boom' of prey abundance, largely as a result of access to artificial watering points. The extended spring and early summer dry periods preceding the surveys of 1999 allowed bilbies not exposed to this predator pressure to recruit to the population, and thus increase population size, even though the core burrow areas had declined.

The contraction in core burrow areas is likely to expose outlying low-density areas of bilbies to increased risk of local extinction. The bore capping and piping scheme being supported by the State and Federal Governments in the area is likely to exacerbate this problem. It allows grazing to be conducted over a much wider area, which could be expected to result in further losses in biological diversity and increased influence of exotic predators that would benefit from increased hunting ranges as a result of additional water. If the point water sources shown in Fig 6.8 are extended out several kilometres in three or four directions, the potential area of impact will be greatly increased, with enormous impact likely to be wrought on many species, including bilbies.

The populations of bilbies in the stony plains to the north and northeast of Birdsville are likely to be the most threatened given their low densities, fragmented occurrence and proximity to resident populations of foxes in the adjacent to the dunefields of the Simpson Desert. The population of bilbies on the eastern side of the Diamantina River channels showed a large decline over 5 years between 1994 and 1999. This most eastern population in Queensland can also be considered threatened with local extinction if threatening processes continue, since this population is isolated from the core populations in the ashy plains of Astrebla Downs National Park and Coorabulka to the northeast, by the extensive network of the Diamantina

River channels. These are considered a physical barrier and hostile environment for bilbies due to the enhanced predator environment that they afford via increased vegetation cover, and diversity and abundance of riparian prey.

## **7.2 CONSERVATION MANAGEMENT OPTIONS**

The four 'Rs' that could be applied to conservation management in the channel country landscape could be considered to be: *Research, Reserve, Reintroduce, Re-educate*. These are explored below.

### **7.2.1 *Increased knowledge base***

It is critical to continue expanding our knowledge of the ecology of arid landscapes including the complex interactions between introduced species in these fragile systems, if we are to maintain populations of the unique species that these areas harbour. It is to be hoped that long-term work will continue on the ecology of bilbies in the small areas that remain in Queensland.

Long-term studies are critical in these environments since the ecosystem changes are dynamic over long time frames that are determined by the timing, frequency and extent of rainfall events. This was the case in 1992 when the rat and cat populations exploded in the area. This event has not been repeated in the 12 years since; however, it will occur again, and if we do not respond we could very well lose many vulnerable species. Long-term studies are being conducted in the northern Simpson Desert by University of Sydney staff. These will jointly assist our attempts to understand the ecological complexities of arid landscapes in the region.

### **7.2.2 *Predator management***

The instigation of an integrated broadscale predator management strategy is critical if we are to prevent regional depletion in numbers of native species. Ultimately, continued regional

depletions will lead to complete losses of populations of some species. The strategy could be approached in two ways:

- i) The most cost effective predator control method is to aerial bait with 1080 in the vicinity of all watered areas (bores, dams, waterholes), particularly during dry times. A baiting program would need to be coordinated and involve all landholders in the area. Funding assistance for such a program could be sought from all levels of Government. One problem may be encountered with the organic beef industry in the area, which restricts the use of chemicals.
- ii) An indirect way of targeting predators would be to restrict their access at least to the many artificial water sources that provide water *ad libitum* all year round for stock and anything else. At a property management level this could involve turning waters off when stock are removed from areas during dry times. This would necessitate reconditioning of many of the flowing bores that can't be turned off because of deterioration in the bore casing below ground level. The Queensland Department of Natural Resources and Mines is currently supporting this process as a water conservation initiative. A better alternative would be to prevent predators gaining access to these waters. This could involve use of water troughs that cattle can access but from which cats, foxes and dingoes are excluded.

### **7.2.3 Captive breeding and reintroduction**

Given the current status of bilby populations in Queensland it is imperative that captive populations be established and maintained. Currently there are captive breeding populations of Queensland bilbies at Charleville (Queensland Parks and Wildlife Service), Fleay's Wildlife Park (QLD), Western Plains Zoo (Dubbo NSW), and Scotia Sanctuary (south of

Broken Hill, NSW). Non-breeding populations are held at Dreamworld (QLD) and Currumbin Sanctuary (QLD). The species breeds readily in captivity.

A reintroduction project is currently underway in Queensland and the first animals are due to be introduced in spring of 2004. An enclosed predator proof area of 29 km<sup>2</sup> has been completed and all exotic species have been removed. This project is similar to that reported by Moseby and O'Donnell (2003) at Roxby Downs in South Australia, except that only bilbies will be introduced whereas in their project multiple endangered species have been introduced. Reintroductions have also occurred at Dryandra and Shark Bay in Western Australia and Thistle Island in South Australia.

Reintroductions not only provide genetic security in the event of a catastrophic crash of wild populations, but also the opportunity to test some of these predator-prey interactions where vital elements in the predator equation can be manipulated and controlled. This work can provide valuable information not only for the future expansion and dispersal of re-introduced bilby populations; but also on the role of predators. This will benefit the management of other species identified as being in the early stages of decline. Southgate (1994) suggested that reintroductions should be used to explore the underlying processes that have contributed to declines in the wild, with the prime aim of understanding these, to ameliorate the conservation status of wild populations. The bilby is a useful species to work with in this regard since it possesses a suite of biological and ecological attributes that make it eminently suitable for such studies.

#### **7.2.4 Conservation Reserves**

There is little need for additional conservation reserves in the region, particularly if landholders can be cooperatively involved in reducing predator numbers across the landscape. There are three large National Parks in the region of the current bilby populations in Queensland. The Australian Bush Heritage Trust acquired "Ethabuka" in the

northern Simpson Desert recently (February 2004), and this acquisition provides a substantial additional conservation area.

Conservation Reserves are vital in that they at least provide areas where the impacts of grazing by domestic stock have been removed. This will allow investigation of the impacts of long-term grazing on plant species diversity and cover, with flow-on impacts to native fauna. However, unless predation by dingoes, foxes and cats is targeted in the management of these areas, many small to medium sized mammals will be ecologically no better off. This applies particularly to the bilby, since it is not an arid zone specialist.

### ***7.2.5 Community Education***

It is vital that the ecological values of this special part of Queensland are brought to the attention of the community at large. The amount of scientific studies that have occurred in the area over the years is substantial and, I think if popular accounts or summaries of these collected works were available to people living in the area, great gains could be made in closing the barriers between science and the community. David Akers from the Longreach office of Queensland Parks and Wildlife Service has been making great advances in this area in recent years and his work needs to be extended. The message, that the area is one of the least affected by pastoral development by Europeans in Queensland, needs to be conveyed, and conveyed in a non-threatening, cooperative and consultative manner.

The majority of grazing leaseholders in the present study area were unaware of, nor concerned about, the presence and/or conservation status of the native faunal species within the bounds of their leases 20 years ago when the Diamantina Shire fauna surveys were about to commence (R. Atherton pers. comm.). This is quite understandable and acceptable given the lack of awareness and understanding of conservation issues in arid lands in Queensland at the time. Also, with respect to mammals at least, most species are small, cryptic and strictly nocturnal, hardly a set of features that lend themselves to observation by people working long hours during daylight.

Times have changed now and there is a growing awareness within the community relating to nature conservation and biodiversity. We have seen the emergence and acceptance of Landcare groups, and the need for total catchment management groups such as the Murray-Darling Basin and Lake Eyre Basin catchment committees. All of these have contributed to a greater awareness concerning the wise use of our natural resources.

Of course, it has not always been evolving conservation awareness that has resulted in the acceptance of these groups/committees. The recent strong resistance to water extraction on Cooper Creek at Windorah provides a good example (personal observation). In this instance we have seen not so much the emergence of a 'green' or conservation ethic in the channel country but rather, a 'conservative' reaction to a proposed development impinging on the perceived 'rights' (income and life style) of those people living there. The reaction gained widespread public support and credibility by its ability to embrace the conservation and scientific communities. The outcome has had positive conservation benefits despite the differing philosophies involved; and has probably seen an unprecedented 'rapport' develop between groups that previously would have been diametrically opposed on conservation grounds. This has resulted in a narrowing of the 'conservation gap' between the rural community and the conservation community and can only be regarded as a positive outcome. We need to convey the message that the efforts to stop cotton growing on Cooper Creek are no different to any efforts in terms of trying to prevent declines in landscape quality and biological diversity. Further, we cannot on the one hand say that extraction of water for cotton growing from a major water course (albeit ephemeral, as are all drainage systems in the arid zone) will result in an ecological disaster, and on the other hand continue to tap into the Great Artesian Basin, dam minor drainage systems with earth tanks and dams (spreading water across the landscape for stock), with little regard for the direct and indirect ecological implications of doing so.

A comment often presented to me by people in the channel country grazing community in regard to bilby declines in Queensland is: "*we must be doing something right, the bilbies*

*are still here*". Whilst this attitude is somewhat 'short-sighted', in some respects it is correct but not for the reason promoted. We are fortunate that we still have bilbies left, however it is hardly a result of the management effort imparted by the grazing community but rather a fortuitous, indirect and complex set of landscape and biological features that have determined where grazing can occur. Subsequent management has determined the extent of grazing superimposed over the landscape elements. The bilby's biology/physiology/ecology and the absence of the fox, have allowed it to survive in these landscapes, under these imposed conditions.

The bilby has gained a higher public profile largely as a result of the 'birth' of the Easter Bilby concept, which commenced in South Australia in the mid 1970s. The Australian public has embraced the bilby with its unusually large ears, striking colours, 'cuteness' and almost mythical status. Frank Manthey and myself have injected another burst of enthusiasm to educate people about the plight of the bilby over the past 5 years. We have been able to present the bilby as a flagship or ambassador species and use it as vehicle to highlight the declines of a suite of other endangered species, particularly in the arid zone.

It is critical to capitalise on this public support by communicating the conservation issues raised to the channel country communities, hopefully to arrive at a situation where livestock production and conservation ideals can co-exist.

### **7.3 EPILOGUE**

The increased concern and awareness of endangered species by communities across Australia can only benefit the conservation efforts of many Government and non-Government organisations. It is to be hoped that it is not too late. Once species such as the bilby are gone a whole chapter of biological radiation in the unique Australian landscape will be closed and we, as the custodians of the land in this time frame, will be accountable.



200 years of occupation and spread of Europeans in Australia have played a significant part in displacing many of the native species, both directly and indirectly. Perhaps 50-60 thousand years of previous human occupation of the continent has had a similar impact, albeit in a different temporal framework. One is tempted to think in terms of the on-going mega faunal extinctions debate that highlights impacts of human beings wherever they have gone on the planet (see Flannery 1994; Paddle 2000). Perhaps, in the Australian context, the combined impact of 200 years of technological habitation by human beings and 50 000-60 000 years of habitation by human beings with virtually no technology, has had an enormous impact on our faunal (and floral) assemblages. Which is the greater is up for debate; however, we can hardly ignore the massive changes that have occurred in the short space of 200 years. The history of impacts of human beings on the continent is significant, and leaves us in the state we are in today, with the worst record in the world for rates of mammalian extinctions (Burbidge 1998a).

The bilby is a non-specialist omnivore; it has no strict habitat preference; a high reproductive output; it shows little or no seasonality in breeding; is semi-fossorial; strictly nocturnal, and doesn't require free water. In short, if it were not now an endangered species, it could be a pest.

If we lose a species such as the bilby, we are doing something drastically wrong.

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## Appendix I: WARLUS Land Unit Descriptions

(Western Arid Region Land Use Studies (Warlus) Parts VI and II (Wilson *et al.* 1990, Mills 1980).

Following is a listing of Land Unit descriptions relevant to the Landsystems discussed and referred to in this document. The data contained here has been extracted from WARLUS Parts II and VI (Wilson *et al.* 1990, Mills 1980). The only changes made have been of a taxonomic nature with reference to vegetation descriptions, and only in instances where generic or specific names have changed eg *Cassia phyllodinea* has changed to *Senna artemisioides subsp.*

LAND UNIT 45 (estimated 75% of landsystem F1)

Soils:

Shallow to moderately deep, brown cracking clays with a soft, self-mulching surface. A weak crust occurs. Traces of ironstone gravel occur on the surface. Soils are moderately to very strongly alkaline with soft lime present and gypsum usually occurs at depth. Ug5.31, Ug5.32, C and N values are very low to low, K values are high, acid P values are very high, bicarb P values are very low to fair, AWC values are medium to very high, EC is very low to low at the surface increasing to very high values at depth, CI is generally very low but may increase to very high values at depth. Salt levels are mainly due to gypsum. Soils are sodic at depth. *Karoola* - Representative soil analysis: 2, 19, 56, 155.

Vegetation:

Curley Mitchell grass (*Astrebla lappacae*), barley Mitchell grass (*A. pectinata*) open tussock grassland to tussock grassland (PFC 10-50%). The ephemeral grasses *Enneapogon avenaceus* and *Iseilema vaginiflorum* occur frequently and other species infrequently. A large number of forb species may occur, many of them ephemerals which are seasonally abundant. Frequent species include *Atriplex spongiosa*, *Boerhavia diffusa*, *Ipomoea ionchophylla*, *Psoralea cinerea*, *Salsola kali* and *Sida trichopoda*. Other forbs including many from the Asteraceae, Brassicaceae, Chenopodiaceae, Euphorbiaceae, Fabaceae, Malvaceae and Zygophyllaceae occur infrequently. In overgrazed areas, ephemeral grasses such as *Dactyloctenium radulans* and *Iseilema vaginiflorum*, and ephemeral forbs, such as *Amaranthus mitchellii*, *Cucumis myriocarpus*, *Harmsiodoxa puberula*, *Helipterum floribundum*, *Portulaca oleracea* and *Salsola kali*, predominate and form seasonal herblands.

LAND UNIT 46 (estimated <10% of landsystem F1)

Soils:

Very shallow to shallow, brown clays with sandstone floaters and outcrops. Soils are very strongly alkaline with soft lime present. Uf6.31. The surface has very low C and N values, high K values, very high acid P values and fair bicarb values, EC and CI are very low. *Davenport*.

Vegetation:

Seasonally variable sparse - to open-grassland (PFC <15%) dominated by the short grasses *Enneapogon avenaceus* and *E. polyphyllus*, or less commonly *Aristida latifolia*. Scattered tussocks of *Astrebla pectinata* and *Eragrostis xerophylla* are frequently present, while *Iseilema vaginiflorum* and *Tripogon loliiformis* may be present seasonally. Forbs, such as *Heliotropium* spp and *Euphorbia* spp, occur infrequently. Sparsely scattered *Atalaya hemiglauca* trees or tall shrubs are present in some areas.

LAND UNIT 48 (estimated 50-75% of landsystem F2)

LANDFORM:

Level to very gently undulating plains. Slopes <2%.

GEOLOGY:

Fresh Cretaceous *Wilgunya Formation* and Cainozoic clay deposits overlying all geological beds in the area. Klw, Cza.

SOILS:

Moderately deep to deep, red and brown cracking clays with a self-mulching surface. A surface crust may occur. A trace to moderate amounts of ironstone or siliceous gravel occurs on the surface. Weak microrelief may occur where there is thicker surface gravel. Gypsum crystals occur at depth. Coarse sand often occurs throughout the profile. Soils are slightly acid to strongly alkaline. Ug5.32, Ug5.34, Ug5.37, Ug5.36, Ug5.38, Ug5.39. C and N values are very low to low, K values are high, acid P values are predominantly very low to very fair, bicarb P values are very low to fair, AWC values are medium to very high, EC values are very low to high at the surface, increasing to very high values down the profile, CI is very low at the surface and high to very high at depth. Soils are strongly sodic at depth. *Warra*-Representative soil analysis: 10, 29, 38, 61, 76, 104, 127, 154, 184.

VEGETATION:

Barley Mitchell grass (*Astrebla pectinata*) tussock grassland to open tussock grassland, with *A. elymoides* or *A. lappacea* infrequently co-dominant. *Aristida latifolia* occurs frequently, but is rarely abundant. A number of ephemeral grasses including the frequently occurring *Iseilema vaginiflorum*, and infrequently occurring *Dichanthium* spp, *Panicum* spp and others, may be seasonally co-dominant with the perennial grasses. The forb diversity is high, and many species are ephemerals which may also become seasonally prominent. Frequent species include *Abutilon malvifolium*, *Sclerolaena glabra*, *S. lanicuspis*, *Calotis hispidula*, *Crotalaria dissitiflora*, *Euphorbia drummondii*, *Salsola kali*, *Sida fibulifera* and *S. trichopoda*. Other species, including many from the Asteraceae, Brassicaceae, Chenopodiaceae, Convolvulaceae, Euphorbiaceae, Fabaceae, Liliaceae, Malvaceae and Zygophyllaceae, occur infrequently.

LAND UNIT 55 (estimated < 10% of landsystem F2 and 10 - 25% of landsystem P2)

Land form: -

Gently undulating plains to gently undulating rises. Slopes 0-3%.

Geology:

Mantled pediments, fresh rock and deeply weathered rock associated with the erosion of the Tertiary land surface exposing the Cretaceous *Wilgunya*, *Mackunda* and *Winton Formations*. Silcrete cover is derived from the Tertiary *Marion Formation*. K1w, K1m, Kw, Tm.

Soils:

Deep, weakly gilgaied, stony surfaced, red cracking clays. Surface stone may be desert varnished. Soils are neutral to mildly alkaline with gypsum present at depth. A weak surface crust is usually present. Ug5.38. C and N values are very low to low, K values are very fair to high, acid P values are very low to very fair, bicarb P values are very low to fair, AWC is medium to very high, EC values are very low to high at the surface, increasing to very high values at depth, CI values are generally very low at the surface, increasing to very high levels at depth. Soils are sodic at depth. *Marion* - Representative soil analysis: 68, 72, 162.

Vegetation:

An herbaceous open tussock grassland, occasionally sparse tussock grassland, (PFC <10-30%), dominated by barley Mitchell grass (*Astrebla pectinata*), with *A. lappacea* sometimes common. *Aristida latifolia* and the ephemeral grasses *Dichanthium sericeum subsp. humulius* and *Iseilema vaginiflorum* occur frequently,

with the latter becoming seasonally prominent. A large number of mostly ephemeral forbs may be present and seasonally abundant. *Abutilon malvifolium*, *Sclerolaena lanicuspis*, *Calotis hispidula*, *Crotalaria medicaginea* and *Salsola kali* occur frequently, and many other forbs including species of *Bassia*, *Euphorbia*, *Helipterum* and *Sida* occur infrequently. A number of herbs occur only in run-on depressions. These include the perennial grasses *Bothriochloa ewartiana* and *Chrysopogon fallax*, the ephemeral graminoids *Cyperus gilesii* and *Uranthoecium truncatum*, and forbs such as *Craspedia pleiocephala*, *Centipeda thespidioides*, *Minuria integerrima* and *Senecio lautus*.

LAND UNIT 56 (estimated 50-75% of landsystem P1)

#### LANDFORM:

Level to gently undulating plains. Slopes <3%.

#### GEOLOGY:

Mantled pediments, fresh rock and deeply weathered rock associated with the erosion of the Tertiary land surface exposing the Cretaceous *Wilgunya*, *Mackunda* and *Winton Formations*; Ironstone cover is derived from the deeply weathered Cretaceous sediments. Klw, Klm, Kw.

#### SOILS:

Shallow to deep, stony surfaced desert loams and non-coherent clays. The ironstone layer on the surface is thick. Surface textures range from gravelly loamy sands to gravelly sandy clay loams which overlie structured light to medium clays. The surface horizon is massive, often with a vesicular crust. Soils are slightly acid to neutral at the surface and slightly acid to alkaline at depth. Ironstone occurs throughout the profile and usually increases with depth. The non-coherent clays have a crusted surface over a powdery light clay. Structure development in the clays usually improves with depth. NaCl crystals are usually present in non-coherent clay. Dr1.12, Dr1.32, Dr2.12, Dr2.13, Dr2.32, Dr2.33, Dy1.12, Dr1.3, Dy2.13, Uf1.22, Uf1.23. C and N values are very low, K values are very low to high, acid P values are very low to fair, bicarb P values are very low, AWC values are low to high. Soils with a vesicular crust have a medium to very high values at depth. The other soils have a very low EC and CI values at the surface. Soils are very strongly sodic. *Sturt - Brighton* - Representative soil analysis: 43, 46, 174.

#### VEGETATION:

Sparse grassland or herbland (PFC <5%) dominated by the short grasses *Aristida contorta*, *Oxychloris scariosa*, *Sporobolus actinocladus* and *Enneapogon* spp, and forbs *Sclerolaena lanicuspis*, *S. divaricata*, *Maireana dichoptera* and *Portulaca oleracea*. The ephemeral grasses *Brachyachne prostratus*, *Eriachne pulchella* and *Tripogon loliiformis* occur frequently, while perennial grass *Eragrostis xerophila* may be locally prominent. A range of ephemeral and perennial forbs occur infrequently, many of them from the Chenopodiaceae. When associated with the northern residuals, the ephemeral forbs *Gunnipopsis zygothylloides*, *Atriplex cornigera*, *Sclerolaena eriacantha*, *S. intricata*, and *S. minuta* are frequently present in this unit.

LAND UNIT 59 (estimated 10-25% of landsystem F1 and 10-25% of landsystem P1).

#### LANDFORM:

Level to gently undulating plains. Slopes <2%.

#### GEOLOGY:

Fresh and deeply weathered Cretaceous *Wilgunya*, *Mackunda* and *Winton Formation* sediments with ironstone gravel on surface. Ironstone cover is derived from the deeply weathered Cretaceous sediments. Klw, Klm, Kw.

#### SOILS:

Moderately deep to deep, weakly gilgaied, crusted, red cracking clays. Moderate to large amounts of ironstone gravel occur on the surface with traces throughout the profile. Soils are neutral to moderately alkaline. Ug5.37, Ug5.38. C values are very low to low, N values are very low, K values are very low to high, acid P values are low to high, bicarb P values are very low to low, AWC is medium to high, EC and CI are very low at the surface and high to very high at depth. *Lucknow* - Representative soil analysis: 13.

#### VEGETATION:

Sparse grassland to sparse herbland (PFC<10%). Dominant grasses include perennial *Astrelba pectinata*, and the short grasses *Aristida anthoxanthoides*, *Enneapogon avenaceus* and *Sporobolus actinocladus*. The ephemeral grasses *Dactyloctenium radulans* and *Iseilema vaginiflorum* may become seasonally abundant (PFC 5-20%) and dominant. A number of ephemeral forbs species may be present. Dominant species include *Sclerolaena glabra*, *S. lanicuspis* (PFC <5-10%), and *Atriplex lindleyi*, *A. spongiosa*, *Portulaca oleracea*, *Salsola kali* and *Neobassia*

*proceriflora*. Other forbs from the Asteraceae, Brassicaceae, Malvaceae and other families occur infrequently.

LAND UNIT 60 (estimated >75% of land system P2)

Landform:

Level to gently undulating plains. Slopes <3%.

Geology:

Mantled pediments, fresh rock and deeply weathered rock associated with the erosion of the Tertiary land surface exposing the Cretaceous *Wilgunya*, *Mackunda* and *Winton Formation* sediments. Quaternary alluvia. Silcrete cover is derived from the Tertiary *Marion Formation*. Klw, Klm, Kw, Tm, Qa.

Soils:

Moderately deep to deep, gravelly surfaced desert loams and minor red clays. Very weak gilgai surface. The massive, slightly acid, fine sandy loam to clay loam fine sandy surface horizon overlies a well structured, neutral to alkaline, medium clay subsoil. A vesicular crust occurs on the surface. Gypsum occurs at depth. Non-coherent clays may be locally dominant. They have a surface crust overlying a soft powdery clay. NaCl crystals occur in profile. Reaction trends to be neutral. Minor red, crusted, non-cracking clays occur. Dr1.12, Dr1.32, Dr1.33, Dr2.13, Dr2.32, Dr2.33, Dy1.12, Dy1.32, Dy2.12, Dy2.13, Dy2.32, Uf1.22, Uf1.23, Uf6.31, C and N values are very low, k values are low to high, acid P values are low to very high, bicarb P values are very low to very fair, AWC is low to very high generally increasing in profile. Soils with a vesicular crust have high to very high EC and CI values throughout the profile while soils without a vesicular crust have a very low EC and CI values at the surface, increasing to very high levels at depth. All soils are strongly sodic at depth while soils with a vesicular crust are strongly sodic throughout. *Sturt - Brighton* - Representative soil analysis: 100, 163, 165, 169, 177.

LAND UNIT 61 (estimated 50-75% of landsystem P3)

Landform:

Level Plains. Slopes 0-1%.

Geology:

Superficial clay plains overlying deeply weathered Cretaceous *Winton Formation* sediments. Kw.

Soils:

Shallow to deep, gravelly surfaced desert loams. The abundant surface gravel is usually a mixture of ironstone chalcedony, laterite and silcrete. The massive, hard setting and crusty surface horizon overlies a well structured medium clay subsoil. Reaction trends are neutral or alkaline. A vesicular crust occurs on eroded soils. Dr1.32, Dr2.12, Dr2.13, Dr2.32, Dr2.33, Dr2.42, Dy1.13, Dy2.13. C and N values are very low, bicarb P values are very low, AWC is low at the surface, increasing to medium to high at depth. EC and CI are very low. *Cluny* - Representative soil analysis: 151, 153.

Vegetation:

Sparse to open herbland (PFC <5-15%), dominated by the short grass *Aristida contorta* and ephemeral forbs *Sclerolaena lanicuspis*, *Gnephosis foliata*, *Helipterum floribundum* and *Stenopetalum nutans*. The perennial grass *Aristida latifolia* and ephemerals *Enneapogon avenaceus* and *Tripogon loliiformis* occur frequently, as do the forbs *Lepidium rotundum* and *Sida fibulifera*. A variety of other forbs occur infrequently and include species of *Atriplex*, *Calotis*, *Goodenia*, *Portulaca* and *Ptilotus*. Sparsely scattered *Acacia tetragonophylla* and *Cassia phyllodinea* shrubs (Ht <1-2m) are frequently present, while *Cassia* spp, *Hakea* spp and other trees and shrubs occur infrequently.

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