CHAPTER 3

SITES AND GENERAL METHODS

3.1 OVERVIEW

This chapter provides detailed descriptions of the three study sites. Three sites were used because the distributions of the three wombat species are non-sympatric. This chapter also provides a brief overview of the methodologies used. Detailed information on the various methods is given in the chapter to which each is most relevant. The type and level detail of information I collected varied between wombat species, and depended on existing information, information being obtained from other current research projects on wombats, accessibility to sites and time constraints. The major part of this study was devoted to the common wombat. For this species I collected information on the nutritional ecology (food availability, nutritional quality of food resources, diet, digestive efficiency), habitat use (home ranges) and energetics (body condition, field metabolic rates, field water turnover rates, activity levels). Information on the nutritional ecology of this species was collected during each of the four seasons over two years. Most of the habitat use and energetics data were collected during the seasonal extremes (in terms of food resources) of summer and winter. Activity data were collected continuously over many months via the use of data loggers attached to collars worn by common wombats. For the two hairy-nosed species, I collected information on their energetics but not on their nutritional ecology or habitat use. I had planned to collect the energetics data for these two species once during each of the summer/winter seasonal extremes, and was

able to do this for the southern hairy-nosed wombat, but not for the northern hairy-nosed wombat. Low capture success for the northern hairy-nosed wombat meant that energetics information was obtained during the dry winter but not during summer. I did not collect activity data for the northern hairy-nosed wombat (since this formed part of a project by another researcher) but I did collect activity data for the southern hairy-nosed wombat over an eight-month period (between the two energetics sampling times) using data loggers.

3.2 SITE SELECTION

Northern hairy-nosed wombats were studied at Epping Forest National Park in Queensland, their only known extant site. Southern hairy-nosed wombats were studied at Brookfield Conservation Park in South Australia, an area that had been specifically set aside for the conservation and research of this species. This site had the advantage of having a sufficiently high population size to guarantee reasonable trapping success, low levels of human interference (since it was a protected area) and on-site research facilities. The site for common wombats was chosen after extensive searches through the State Forests and freehold land along the Great Dividing Range between Nundle and the Oxley Highway (the closest area to Armidale where wombats were known to occur). Talks with local farmers and Forestry personnel enabled me to identify places of relatively high wombat abundance. The site in Riamukka State Forest was chosen for its high abundance of common wombats, low level of human interference, ease of access, representativeness of common wombat habitat and its close proximity to Armidale.

3.3 RIAMUKKA STATE FOREST, NEW SOUTH WALES

3.3.1 Location

This study site was located in Riamukka State Forest at 151°43'E, 31°20'S approximately 40 km south of Walcha and 80 km south of Armidale, NSW (Figure 3.1). The site was situated on the crest of the Great Dividing Range at 1300 m asl and encompassed an area of approximately 200 ha of forest and open pasture. Riamukka SF

is bounded by Tuggolo SF to the west and Enfield SF to the east. Together, these State Forests form a continuous tract along the Great Divide. Riamukka SF is bounded by cattle grazing properties to the north and south. The study site lies on the division between the catchments of the Manning and Macleay river systems. A small (60 ha) area of cleared freehold land is located within Riamukka SF, and part of this was encompassed by the study site.

This site lies at the northern extreme of the (mostly) contiguous portion of the distribution of the common wombat. Small isolated populations have been recorded further north near Stanthorpe, Queensland, and in Butterleaf, Boonoo, Spirabo and Curramore State Forests (Smith *et al.* 1992, Heyward 1996) near Tenterfield, New South Wales (NSW). Recent searches by personnel from State Forests of NSW have failed to locate wombats at some of these locations (Roger Heyward pers comm.). The northerly limit of the main distribution of the common wombat appears to coincide with a marked change in geology, soils, landuse and (to a lesser extent) rainfall which occurs within five to ten km north of the Riamukka study site. Common wombats are abundant throughout Riamukka State Forest and the adjoining State Forests to the east and west. They are also common in the patchily cleared and grazed properties to the south (pers obs).

3.3.2 Climate

The study area falls within the cool temperate zone, experiencing cold winters and mild summers. Rainfall in the region averages around 1200 mm pa. and generally follows a pattern of drier winters and wetter summers (Figures 3.2 and 3.3). On average, around one third of the annual rain falls between December and February. During this period maritime-influenced air masses from the east and tropical-influenced air masses from the north dominate the climate. Thunderstorms and summer rainfall may occur as early as October and extend into March. During the summer months temperatures on average range from about 10°C to 26 °C and rarely exceed 30°C. Temperatures during the winter months range, on average, between 1°C and 10°C and often fall below 0°C. Frosts may occur in the study area from April to November. Bureau of Meteorology records indicate that frosts typically occur on most mornings in July and August and 30% to 50% of mornings in June and September. Snow occasionally falls on the higher areas,

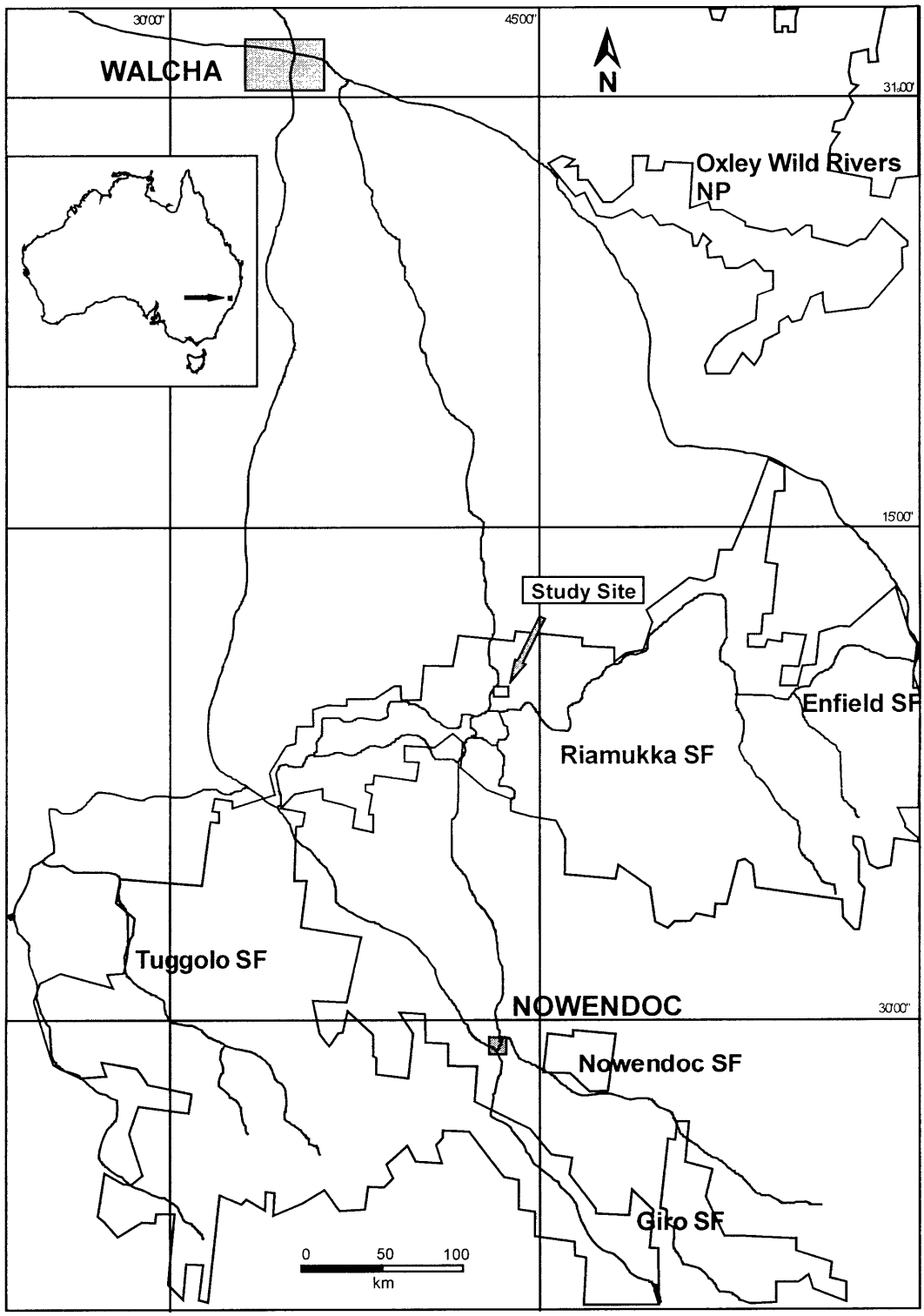

Figure 3.1 Location of Riamukka State Forest and study area for common wombats.

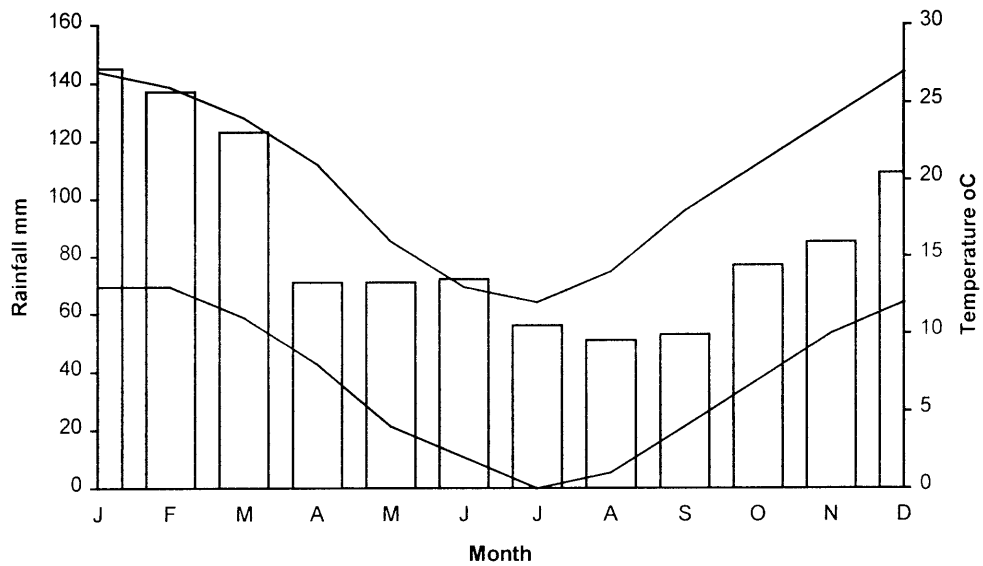

Figure 3.2: Long-term averages for monthly rainfall totals (histogram) for Nowendoc (31°31'S, 151°43'E) (1885 - 1996) and monthly mean daily maximum and minimum temperatures (lines) for Armidale (30°31'S,151°40'E). Nowendoc and Armidale were the closest rainfall and temperature recording stations to the Riamukka site.

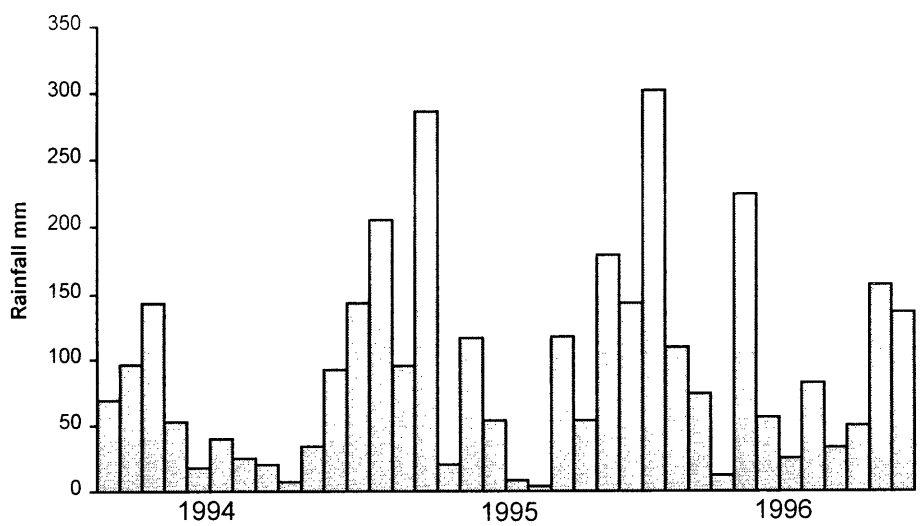

Figure 3.3: Monthly rainfall totals for Nowendoc between January 1994 and December 1996, the period encompassing data collection at the Riamukka site.

including the study site. The region experiences strong westerly to north-westerly winds during the winter months, which may continue into December creating severe fire conditions.

Local climate is influenced by topography, elevation and other factors. The study site, on the west of the Great Dividing Range (section 3.3.3 below), was significantly wetter than areas 10 km away from the summit of the range (pers obs). This extra moisture came from precipitation from clouds that formed above the range and condensation from dense mists or cloud that often enveloped the higher areas, including the study site. These localised weather patterns have the effect of distributing moisture more evenly throughout the year (a higher frequency of 'raindays') than surrounding areas. Pastures in these higher, wetter areas remain greener during the drier months than those further away from the range. High areas of the range also receive stronger winds during winter. Cold temperatures combined with strong winds can result in severe windchill factors. For example, sub-zero temperatures and strong winds (measured with a hand-held wind meter at chest height during night-time fieldwork in August) gave a windchill factor of -17 °C.

Good and Poor Seasonal Extremes

Aspects of this study required good and poor seasonal extremes in pasture quantity/quality be identified. These seasonal extremes needed to identified before seasonal pasture biomass sampling and nutritional quality analyses could be completed (which would have allowed quantitative determination of these seasons). I therefore used qualitative observations of pasture, data for rainfall and temperature, and discussions with local graziers to infer which seasons were most likely to be good and poor. From qualitative observations at the Riamukka site during the early stages of the study, pasture appeared to be at its highest biomass during summer and early autumn, and lowest biomass during winter. Pasture was also much greener during summer than in winter when frosts or snow browned the grass. These observations were supported from comments by local graziers and from rainfall and temperature data (Figure 3.2). Temperature appeared to be the main determinant of pasture growth, as all seasons received abundant rainfall. Warm temperatures and adequate rainfall in summer are

suited to pasture growth, whereas cool to cold temperatures in winter are less conducive to pasture growth. December to March was therefore chosen as the good season (with the reasonable assumption that greener pasture was also more nutritious than browned pasture) and June to August was chosen as the poor season. Biomass sampling later confirmed these months as being seasonal extremes in pasture biomass (Chapter four).

3.3.3 Topography and Soils

The study site encompassed a small rounded hill situated at 1300 m asl on the crest of the Great Dividing Range. The site included the northern, western, southern and to a lesser extent, eastern slopes of this hill. The main ridge of the Great Dividing Range at this point runs in an east-west direction. To the north is the elevated and gently undulating New England Tablelands, a broad and mostly cleared plateau that forms part of the Great Divide. To the south lies a forested escarpment that falls away steeply into the Cooplacurripa Creek valley, a tributary of the Manning River. The study site is bounded to the east and west by two small permanent streams.

The dominant soil of the study site was a red krasnozem, a highly fertile clay loam of low erodability (Anon. 1995). This soil is derived from the underlying Tertiary Volcanic rocks (mostly basalts) that form a cap on some of the higher areas in the region. Soils to the north of the site are derived from sedimentary material and are pale, sandy and of lower fertility, whereas those to the south are similar to that of the study site.

3.3.4 Vegetation

I divided the site into three areas based on broad vegetation structure (Figure 3.4). 'Forest' included eucalypt forest that occupied the southern 40% of the site. 'Woodland' was present on the western slope and 'Cleared' occupied the remaining 40% of the area to the north. These broad vegetation types are described in detail below.

Forest

The eucalypt forest on the crest and southern slope of the study site was a tall open grassy forest dominated by messmate stringybark *Eucalyptus obliqua*, together with

snowgum *E. pauciflora*, silvertop stringybark *E. laevopinea*, diehard stringybark *E. cameronii*, New England blackbutt *E. campanulata* and Sydney blue gum *E. saligna*. The understorey was generally a dense cover of tussock grasses and herbs, dominated by snow grass *Poa* spp., lomandra *Lomandra longifolia*, bracken *Pteridium esculentum* and the ferns *Calochlaena dubia* and *Blechnum nudum*. A shrub layer that was dominated by tree ferns *Dicksonia antarctica*, was present in some places, particularly in the moister gullies.

Woodland

Open grassy woodland dominated by snowgum and black sally *E. stellulata* and to a lesser extent mountain gum *E. dalrympleana* was present on the western slope of the study area. The understorey consisted of a dense cover of tussock grasses (*Poa seiberiana* and *P. labilardieri*) and other grasses such as kangaroo grass *Themeda australis*, Sorghum *Sorghum* sp., *Anthoxanthum odoratum* and *Holcus lanatus*. Blackberry (*Rubis fruiticosus*) thickets have invaded some areas.

Cleared area

The gently undulating northern slope of the study area has largely been cleared and replaced with a mixture of native and introduced pasture species. This open pasture is part of a section of freehold land wholly contained within the State Forest. Introduced pasture species present were mainly cocksfoot *Dactylis glomerata*, rye grass *Lolium rigidum* and clover *Trifolium repens*, with the native grasses being mostly *Microlaena stipoides*, and snow grasses *Poa seiberiana* and *P. labillardieri*. Bracken was common and dense blackberry thickets were scattered throughout the pasture. This area is grazed by cattle.

Plate 4 Common wombat habitat, Riamukka State Forest. View to the north-east across cleared padocks of the study site during summer. Tussock snow grasses (*Poa seiberiana* and *P. labilardieri*) dominate the pasture.

Plate 5 Common wombat habitat, Riamukka State Forest study site. The steep banks of narrow tree-fern lined creeks are favoured burrowing sites.

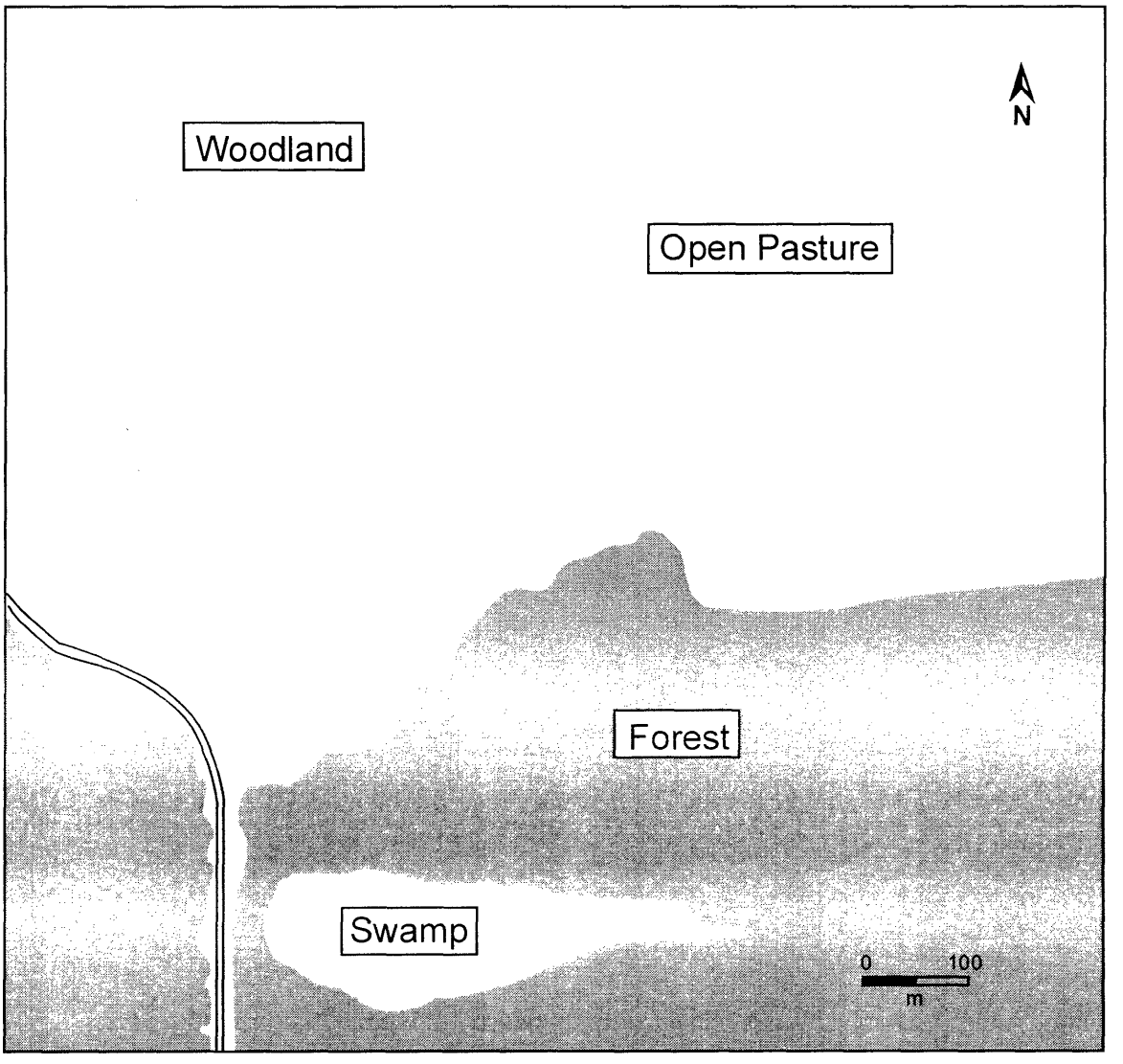

Figure 3.4 Major vegetation communities at the study site in Riamukka State Forest

3.3.5 Mammal Fauna

Other mammals that I have commonly seen at the site include the eastern grey kangaroo *Macropus giganteus*, red necked wallaby *Macropus rufogriseus*, swamp wallaby *Wallabia bicolor*, common brushtailed possum *Trichosurus vulpecula*, greater glider *Petauroides volans*, common ringtail possum *Pseudocheirus peregrinus*, sugar glider *Petaurus breviceps*, and echidna *Tachyglossus aculeatus*. Opportunistic trapping for small mammals during this study revealed the presence of bush rats *Rattus fuscipes* and brown antechinus *Antechinus stuartii*. Rabbits *Oryctolagus cuniculus*, foxes *Vulpes vulpes* and wild pigs *Sus scrofa* were also common at the site. Damage to pasture from rooting by wild pigs was evident during the study. Less commonly seen at the site were cats *Felis catus* and hares *Lepus capensis*. I observed spotted-tailed quolls *Dasyurus maculatus* on two occasions, once when one was caught in a wombat trap after emerging from a wombat burrow.

3.3.6 Land-Use

The region has a long history of timber harvesting (which began in 1850s) and grazing by sheep and cattle. Logging in Riamukka SF began in the 1930s and continues to the present. Large areas of this forest, however, have not been previously logged and some is protected as 'old growth' forest. The study site is part of a recent addition of freehold land to the state forest and I was not able to obtain information on its past logging history. There is, however, evidence that the site has been selectively logged many years ago. Riamukka SF is also used for cattle grazing though cattle in the State Forest at the site were absent or rare. Part of the study site encompassed cleared freehold 'improved' pasture and this was grazed by cattle throughout the study period. Harvesting of eastern grey kangaroos occurs on this property and hunting of wild pigs with dogs and shooting of kangaroos, wallabies and common wombats occurs on private properties and in the State Forest (pers obs).

3.4 BROOKFIELD CONSERVATION PARK, SOUTH AUSTRALIA

3.4.1 Location

Brookfield Conservation Park is located in the Murray Valley region of South Australia and lies approximately 100 km north east of Adelaide and 10 km west of Blanchetown (Figure 3.5). No watercourses or permanent water exist on the park and the major river system of the region, the Murray River, is 10 km to the east. The 5527 ha park is surrounded by sheep grazing properties.

3.4.2 Climate

The region experiences a semi-arid Mediterranean climate, characterised by low winter-dominated rainfall, mild winters and warm summers (Figures 3.6 and 3.7). The park is located in the southern-most extension of the arid zone of South Australia, an area formed by the rain-shadow of the Mount Lofty Ranges. Rainfall at nearby Blanchetown is low and irregular, averaging 248 mm pa. The nearest location where long-term temperature data are available is Waikerie, approximately 50 km to the north east. Average maximum and minimum daily temperatures during January (the hottest month) are 32.8 °C and 15.2 °C. The highest recorded temperature is 46.5 °C. Average maximum and minimum daily temperatures during July (the coolest month) are 16.2 °C and 5.3 °C. Using the measure of drought frequency determined by Trumble (1948), the area has recorded a drought frequency of 78 per cent over the last fifty years. The park, therefore, lies in the most drought prone portion of the present range of the southern hairy-nosed wombat (Wells 1973).

Good and Poor Seasonal Extremes

As mentioned in section 3.3.2, aspects of this thesis required the seasonal extremes (good and poor seasons) to be identified in terms of pasture biomass and quality. Pasture sampling for biomass and nutritional quality was not undertaken at the Brookfield CP site. I therefore identified good and poor seasons from qualitative observations of seasonal pasture growth (biomass) and greenness, discussions with local graziers and researchers, and from rainfall and temperature data. According to local

knowledge and opportunistic observations pasture growth, this semi-arid area is largely driven by rainfall, not temperature. Winter months are more favourable for pasture growth as rainfall is winter dominated and high summer temperatures quickly dry out soils. June to September was chosen as the good season and December to February was chosen as the poor season. Sampling was undertaken at the end of the cool wet winter (good season) and at the end of the hot dry summer (poor season), which are likely to correspond to the seasonal extremes in pasture biomass and quality.

3.4.3 Topography and Soils

The park is a gently undulating limestone plain comprised of a layer (approximately 1 to 3 m thick) of calcrete overlying Miocene limestone. The discontinuous soils are thin and poorly developed, and flat-pan drainage/evaporation basins are common. During the dry summer, free water may be available for a short period following rainfall. Because rainfall is infrequent at this time, free water is rare and may not be present on the park for many weeks. During the summer field trip, free water disappeared within 2 days of rainfall and no free water was present on the park for 5 weeks.

3.4.4 Vegetation

Two main vegetation types are found in the park: mallee and open woodland/shrubland. Mallee is a colloquialism for eucalypt species having a number of stems arising from a large underground root stock. Mallee covers most of the north east of the park and a small portion in the south west corner. Dominant trees are red mallee *Eucalyptus socialis*, mallee box *E. porosa*, yorell *E. gracilis* and gidgee *Geijera linearifolia*. The sparse herb layer includes gull weed *Zygophyllum apiculatum*, *Sclerolaena* spp., *Olearia muelleri* and tussocks of speargrass *Stipa nitida*. Woodland/Shrubland occupies the rest of the park and is dominated by sugarwood *Myoporum platycarpum*, *Myoporum montanum*, tea-tree *Melaleuca lanceolata* and gidgee *Geijera linearifolia*.

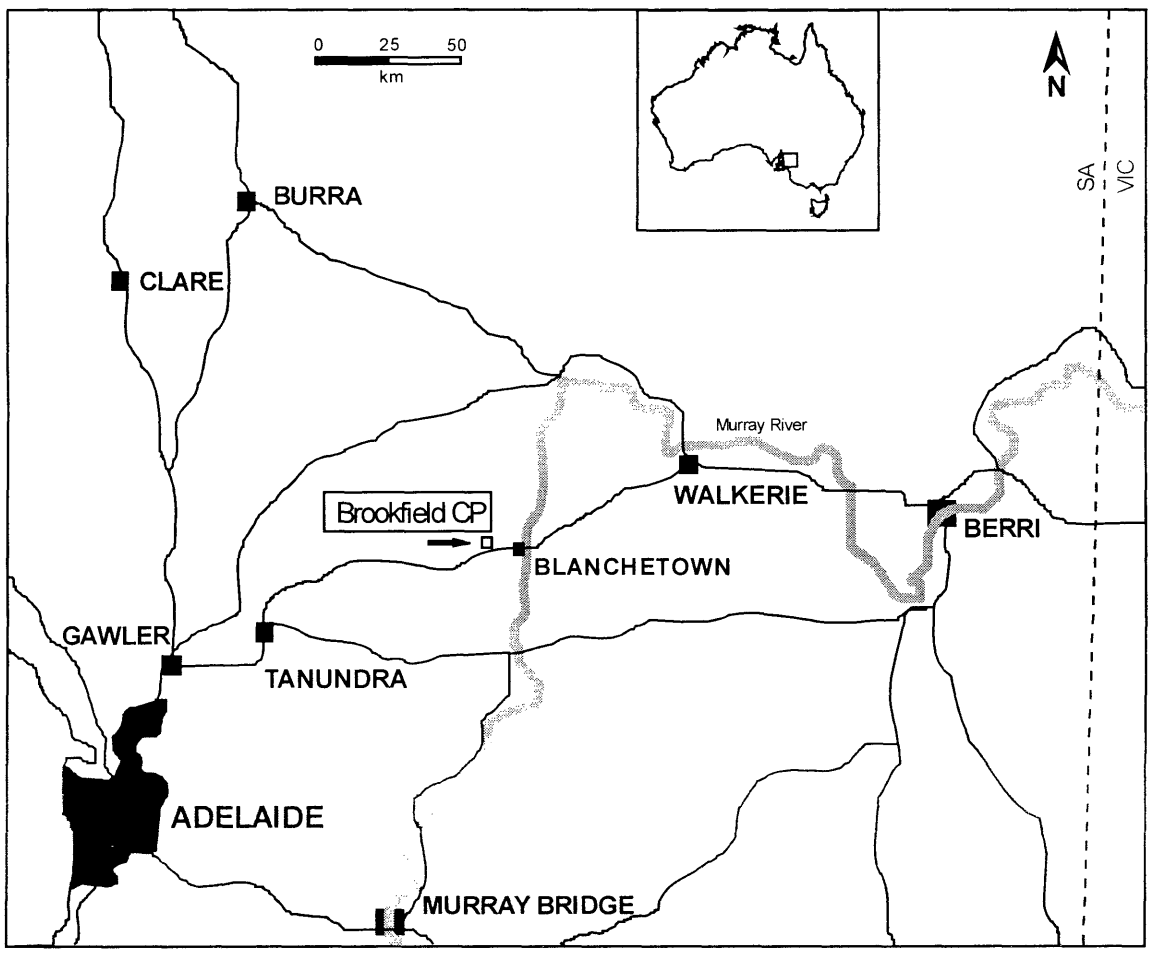

Figure 3.5 Location of Brookfield Conservation Park, the study area for southern hairy-nosed wombats.

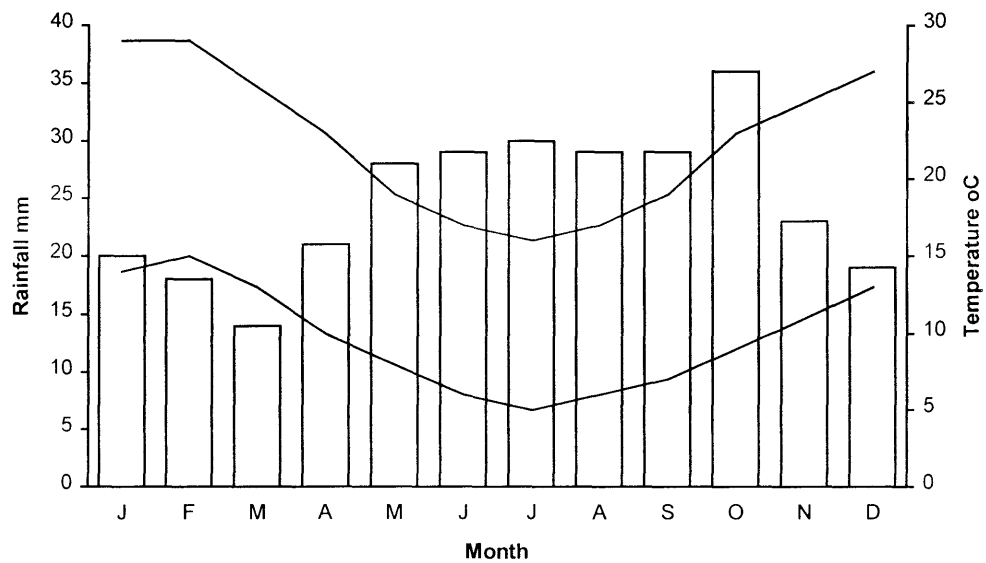

Figure 3.6: Monthly averages for rainfall and temperature in the vicinity of Brookfield C.P. Long-term averages for monthly rainfall totals (histogram) for Blanchetown (34°21'S, 139°36'E) (1968 - 1996) and monthly mean daily maximum and minimum temperatures (lines) for Waikerie (34°31'S,139°40'E).

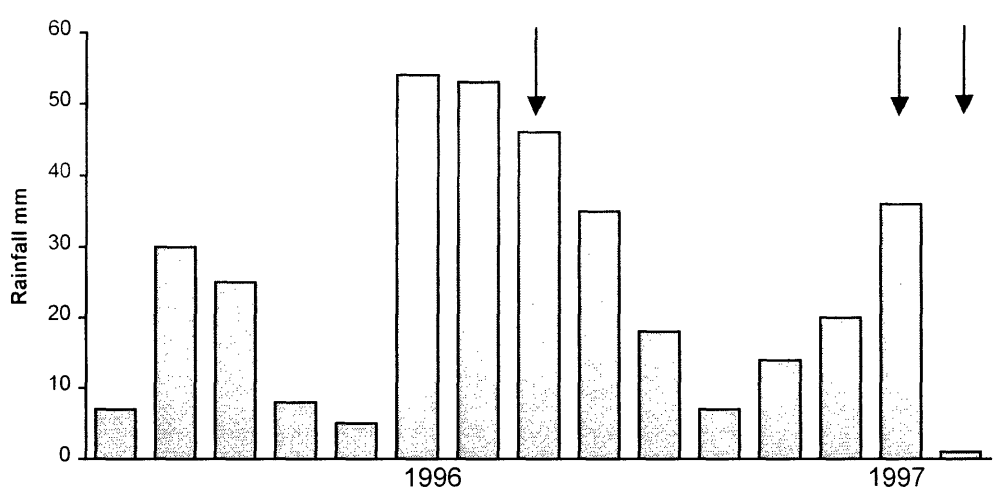

Figure 3.7: Monthly rainfall totals in the vicinity of Brookfield C.P. during the study. Monthly rainfall totals for Blanchetown between January 1996 and March 1997, a period preceeding and including data collection at Brookfield C.P. Arrows indicate sampling periods.

Plate 6 Southern hairy-nosed wombat habit at Brookfield Conservation Park, South Australia. View across Chenopod shrubland during a break in a winter rainstorm.

The shublayer is mostly bluebush *Maireana* spp. and saltbush *Atriplex* spp. The understory is characterised by Australian boxthorn *Lycium australe*, bullock bush *Heterodendrum oleifolium*, caustic weed *Euphorbia drummondii* and heron's bill *Erodium cygnorum*. The introduced Ward's weed *Carichtera annua* dominates the herb layer over much of the park. In the south east of the park, shrubland comprises an even-height stand of regenerating (post-grazing) bluebush.

There is a striking difference in the vegetation between the cool wet winter and the hot dry summer. Following rainfall during a good wet season, much of the shrubland is covered by green herblayer that includes speargrass tussocks and various annual and ephemeral flowering dicots. During summer, the herblayer becomes sparse and 'hayed off', and is dominated by dry, unpalatable Ward's weed.

Southern hairy-nosed wombat burrows occur throughout the park but are rare in the mallee-dominated vegetation communities.

3.4.5 Mammal Fauna

The other abundant mammals on the park (apart from wombats) are the western grey kangaroo *Macropus fuliginosus* and, to a lesser extent, the red kangaroo *Macropus rufus*. There has been a steady increase in kangaroo numbers since the removal of sheep (DENR Brookfield Management Plan). Current high abundance of kangaroos on the park, combined with the level of observable overgrazing on the park, suggests that these macropods might be a significant competitor for food with southern hairy-nosed wombats. Feral goats were present on the park at the time of this study and are currently being controlled by rangers. Stray sheep from neighbouring properties are an intermittent problem. Rabbits were common on the park during the first wombat trapping trip in winter 1996 but were almost absent on the park during the following summer, presumably due to biological control from the recently released rabbit calicivirus.

3.4.6 Land-Use

Land-use in the region is predominantly sheep grazing. In 1971 the Chicago Zoological Society of Brookfield, Illinois, purchased Glen Leslie Station which then

became the Brookfield Zoo Wombat Reserve. The park was given to the South Australian Government (National Parks and Wildlife Service) in 1977 and renamed Brookfield Conservation Park. The objectives of the Park are to provide refuge for southern hairy-nosed wombats, and to provide an area where research can be undertaken. Current management practices include prohibiting grazing by sheep, control of feral animals (mainly goats) and monitoring numbers of kangaroos and wombats. SA NPWS is considering a kangaroo culling program to reduce the numbers of kangaroos on the reserve and hence reduce competition for food with wombats.

3.5 EPPING FOREST NATIONAL PARK, QUEENSLAND

3.5.1 Location

Epping Forest National Park (146° 42'E, 22° 22'S) is located approximately 100 km north west of Clermont in central Queensland (Figure 3.8). The park lies within the Burdekin River drainage system and is situated 12 km east of the major watercourse in the region, the Belyando River. The 3300 ha park is bounded on all sides by cattle grazing properties. The burrows of the northern hairy-nosed wombat (and hence trapping locations) are largely confined to the sandy levee banks of an ancient watercourse that is now present as a barely perceptable wide and shallow gully winding north-south through the middle of the park.

3.5.2 Climate

Epping Forest lies within the semi-arid tropics and experiences mild winters and hot summers (Figures 3.9 and 3.10). The mean annual rainfall of 576 mm is summer dominated (72% of the annual total falls between November and March inclusive) and unpredictable. The three driest months (July, August and September) each average only 3 mm of rainfall. Several long-term droughts, lasting up to 6 years, have been recorded in the area (Gordon *et al.* 1985). Daily maximum temperatures average 34.9°C (but commonly exceed 40°C) during the hottest month (December) whereas daily minimum temperatures in the coolest month (July) average 6.5°C (Johnson 1991b).

Good and Poor Seasonal Extremes

As mentioned in section 3.3.2, aspects of this thesis required the seasonal extremes (good and poor seasons) to be identified in terms of pasture biomass and quality. Pasture sampling for biomass and nutritional quality was not undertaken at the Epping Forest NP site. I therefore identified good and poor seasons from qualitative observations of seasonal pasture growth (biomass) and greenness, discussions with local researchers, and from rainfall and temperature data. Summer months are favourable for pasture growth as rainfall in this semi-arid areas is strongly summer dominated. December to February was chosen as the good season and June to August was chosen as the poor season.

3.5.3 Topography and Soils

The topography of Epping Forest is characterised by an almost flat sandy plain which is intersected by a broad shallow gully winding north-south through the middle of the park. The park is bordered to the east by a semi-permanent creek (Fox Creek). The dominant soils are dry siliceous sands overlying grey clays with deep alluvial sand deposits occuring along the central gully. Internal drainage of these soils has been rated as 'excessive' (Gordon *et al.* 1985). Deep grey cracking clay soils occur in the west of the reserve and these may be extensively gilgaied (formation of clay drainage depressions that form boggy waterholes during the wet season).

3.5.4 Vegetation

Vegetation is typically open grassy eucalypt woodland (Figure 3.11), of which two sub-types were recognised by Catchpoole (1988):

1. Vegetation of the gully is a very open woodland dominated by long-fruited bloodwood *Eucalyptus polycarpa* and Moreton Bay ash *E. tessellaris*, with a few mid-storey species and a grassy understorey.

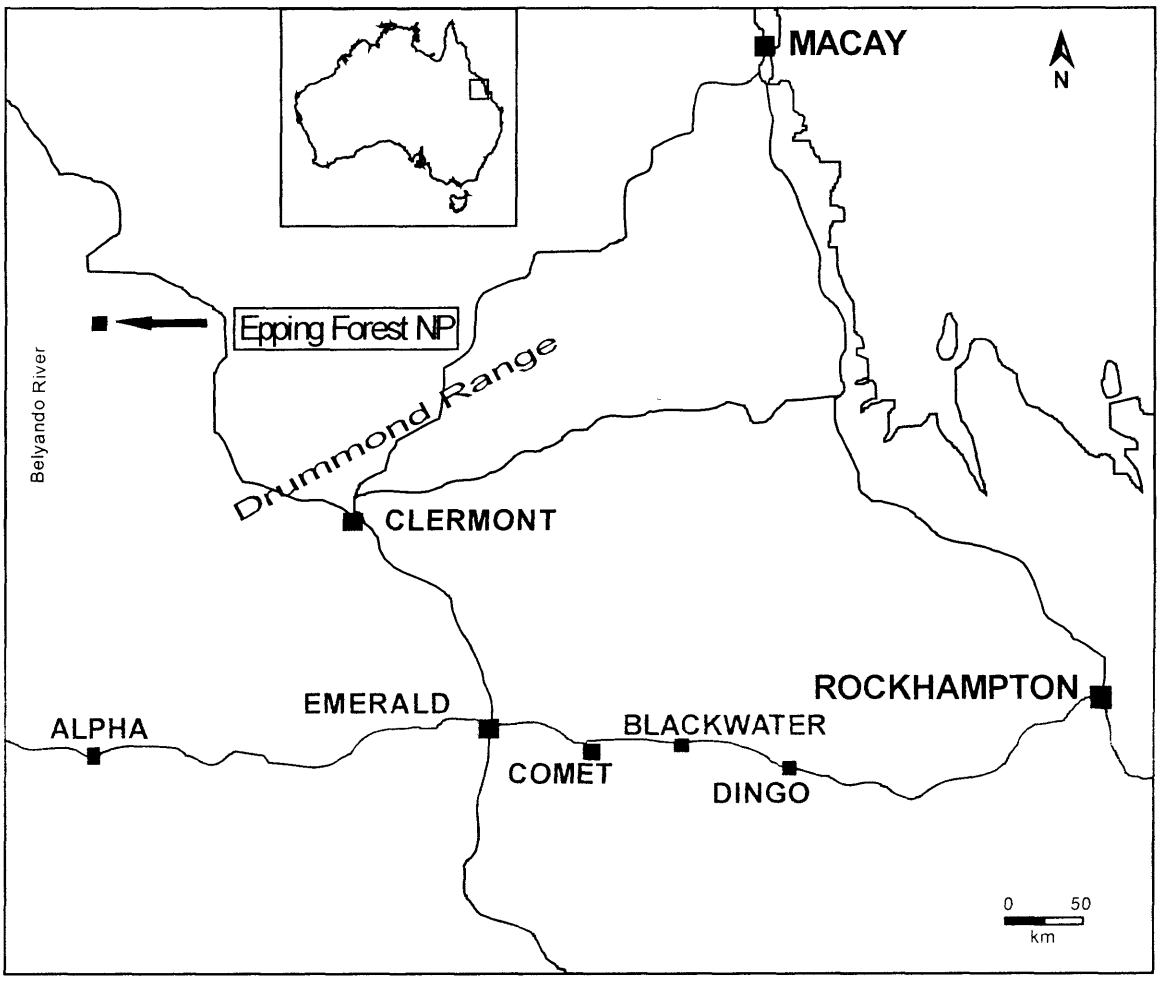

Figure 3.8 Location of Epping Forest National Park, the study area for northern hairy-nosed wombats.

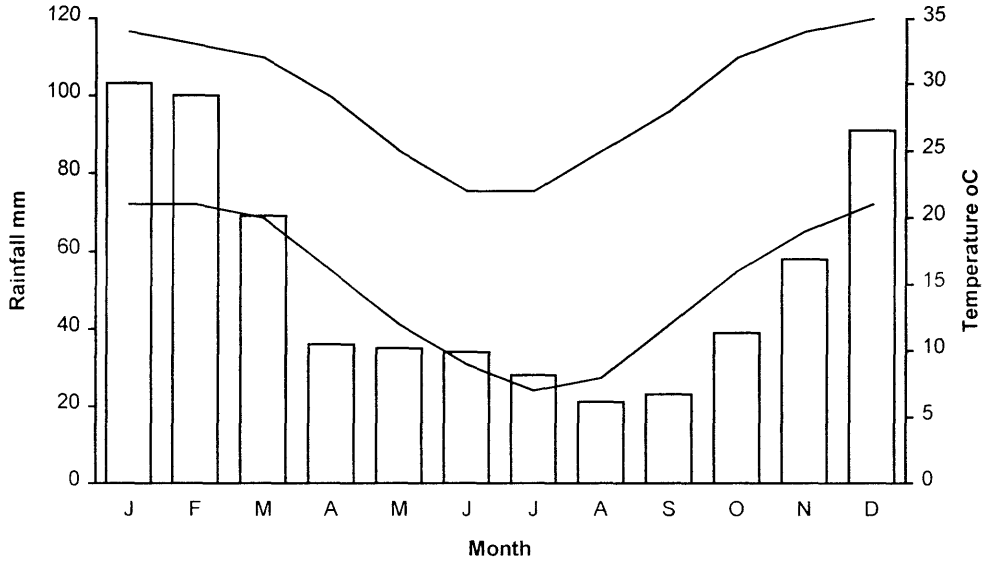

Figure 3.9: Monthly averages for rainfall and temperature in the vicinity of Epping Forest N.P. Long-term averages for monthly rainfall totals (histogram) and monthly mean daily maximum and minimum temperatures (lines) for Emerald (23°31'S, 148°09'E) (1983 - 1996).

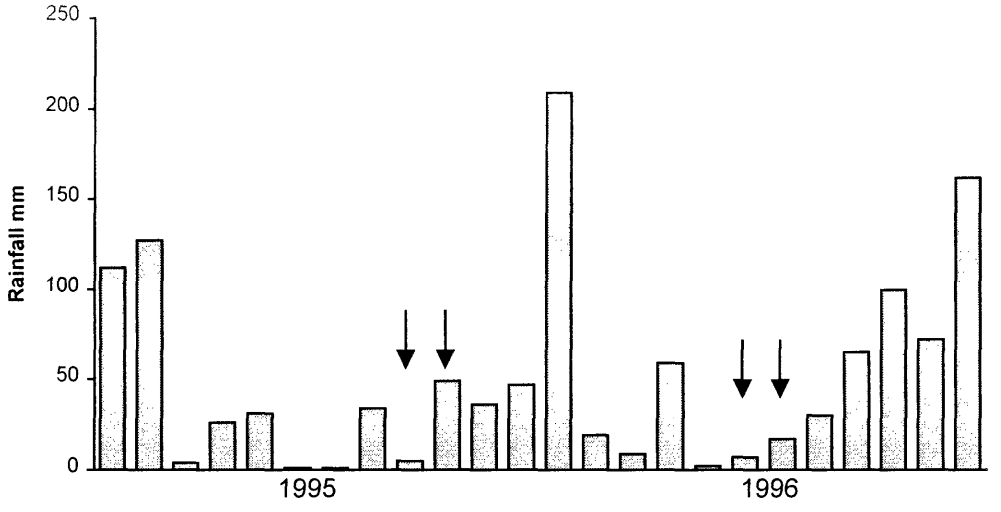

Figure 3.10: Monthly rainfall totals in the vicinity of Epping Forest N.P. during the study. Monthly rainfall totals for Emerald Emerald between January 1995 and December 1996, the two years encompassing data collection at Epping Forest N.P. Arrows indicate sampling periods.

Plate 7 Northern hairy-nosed wombat habitat of Epping Forest Scientific Reserve, Queensland. Open grassy eucalypt woodland typical of the Reserve. The understory is dominated by buffel grass.

2. Other areas consist of a more dense open grassy woodland dominated by poplar box E. populnea with a diverse mid-storey of mostly false sandalwood Eremophila mitchellii, bauhinia Lysiphyllum hookeri, yellow wood Terminalia oblongata, and bullock bush Heterodendrum oleifolium.

Patches of brigalow *Acacia harpophylla* and gidgee *A. cambagei* with a sparce understorey of grasses occur on the grey cracking clays in the west of the Park.

A mixture of native and introduced grasses are present on the Park. Native grasses in wombat feeding areas are dominated by black spear-grass *Heteropogon contortus*, wire grasses *Aristida* spp. and wiry nine-awn *Enneapogon lindleyanus*, although at least 20 species are present (Gordon *et al.* 1985). Buffel grass *Cenchrus ciliaris*, a species introduced by the grazing industry, increased from 13% of the pasture yield in 1987 to become the dominant grass on the Park by 1993 (Horsup and Davidson 1994; pers obs).

3.5.5 Mammal Fauna

Other mammal species that have been sighted on the park by various researchers include the eastern grey kangaroo, red kangaroo, black-striped wallaby *M. dorsalis*, spectacled hare wallaby *Lagorchestes conspicillatus*, rufous rat-kangaroo *Aepyprymnus rufescens*, rabbit, cat and dingo *Canis lupus dingo*.

3.5.6 Land-Use

The land use of the region is predominantly cattle grazing. The area that is now Epping Forest National Park was previously part of the adjacent Epping Forest Station and had been grazed by cattle. Cattle were removed in 1981 following National Park proclamation and the Park has been essentially stock free ever since. Current management practices on the Park include the restriction of access to the park to managers and researchers, maintenance of fire breaks and poisoning (with sodium monofluoro acetate, '1080') of dingoes (a potential predator of wombats).

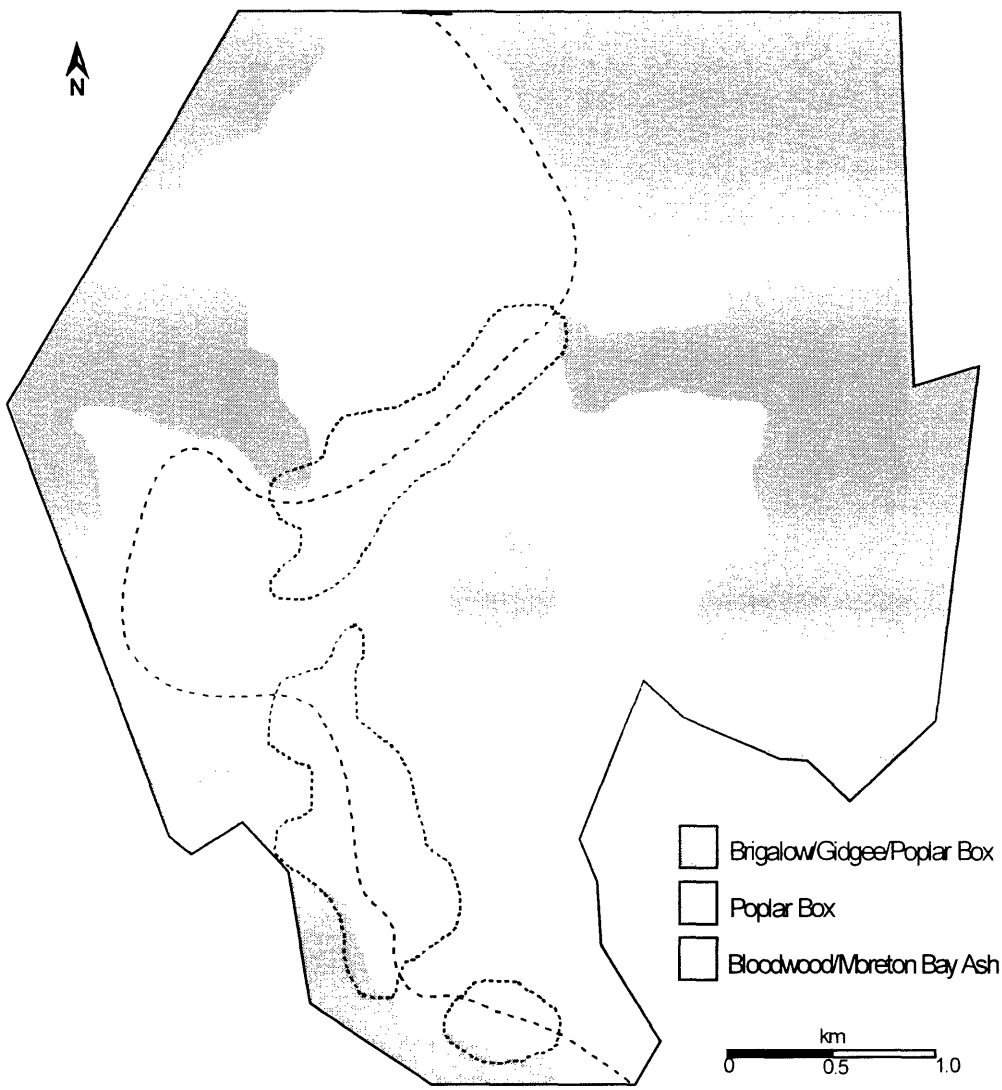

Figure 3.11 Major vegetation communities of Epping Forest National Park. Dashed line = creek, dotted lines = extent of 3 burrow clusters.

3.6 DIET AND FOOD RESOURCES

Field data on diets and food resources were collected for the common wombat but not for the two hairy-nosed species. The diet was determined from analysis of faecal material collected during each season over three years. In conjunction with faecal pellet collections, I determined the seasonal availability of food resources for common wombats by estimating the biomass (in terms of dry weight yield) of each plant species in the herb layer. Biomass estimates were made using the 'Botanal' method which is a combination of the Dry Weight Rank ('tMannetje and Haydock 1963) and Comparative Yield (Haydock and Shaw 1975) methods. The availability of food resources was estimated separately for each of the three vegetation types (forest, woodland and pasture) at the site. I collected foliage samples from potential food species at the same times as data on food availability and faecal pellets were collected, and these samples were later analysed in the laboratory for nutrient content.

3.7 CAPTURE, HANDLING AND COLLARING

3.7.1 Overview

Wombats of each species were caught in large cage traps as they emerged from their burrows during the night and anaesthetised via a blow-dart or hand held syringe. After the animals were measured and weighed they were released back down the burrow. Some individuals were injected with doubly labelled water (as described in Chapters 6 and 7) and were fitted with radio-collars and data logging computers.

3.7.2 Capture

Free-living wombats are wary of being captured and quickly become trap-shy (pers obs). Normal behavioural patterns can be disrupted during and after capture, especially if the animal has suffered a traumatic experience during capture and handling. Individuals may stay down the burrow for a week (and possibly longer) to avoid entering a trap at the entrance of the burrow and may delay emerging from the burrow for several

days after capture even when the trap has been removed (pers obs). For this study it was important to avoid disrupting normal behavioural patterns during the isotope turnover periods since unnatural behaviour will result in spurious values for activity levels, food intake, water turnover and energy expenditure. For these and ethical considerations, the capture methods and use of anaesthesia were aimed at minimising the stress and memory of capture and handling.

There are two common methods for capturing wombats: the use of large cage traps placed in or near burrow entrances (eg Wells 1973; McIlroy 1976; Mallett and Cooke 1986; Crossman 1988) and running down animals with hand-held nets (eg. Wells 1973; Peters and Rose 1979) which may also involve 'stunning' (Robertson and Gepp 1982). I captured all wombats in this study by trapping except for seven southern hairy-nosed wombats that were caught by 'stunning' as part of a pilot study. Wombats were caught in large cage traps as they emerged from their burrows during the night and anaesthetised whilst still in the trap by either blow-darting or the use of a hand-held syringe. The trap design and trapping method varied for each of the wombat species.

Northern hairy-nosed wombat

I trapped northern hairy-nosed wombats in conjunction with Queensland Department of Environment (DoE) and Melbourne University personnel under an existing DoE trapping program. I had previously trapped these wombats whilst working for DoE before this study. The traps used by DoE have proved over a number of years to be a successful design. Two sheet aluminium sliding doors are triggered shut when a wombat touches a strand of nylon fishing line stretched across the path in the centre of the trap. Touching the fishing line sets off a rat-trap which pulls out a pin holding each door up. The spring-loaded rat-trap translates a light touch into a strong force, ensuring that the pins are pulled out and the doors drop shut. The traps are designed so that a wombat can enter from either end, enabling wombats that are either leaving or entering burrows to be caught. The vertical bars (or hoops) of the trap are spaced far enough apart so that a person can reach in and manipulate the animal by hand or inject the animal with anaesthetic via a hand-held syringe, without having to remove the animal from the trap. Burrows of northern hairy-nosed wombats are constructed in a flat plain of loose sand

and usually have a long (2 to 6 m) channel at their entrance which has formed as the roof of the entrance has collapsed progressively back along the tunnel. The most effective method of trapping has been to place the trap in or at the end of the channel and to surround the burrow with a wire netting fence, obliging the animal to pass through the trap. To avoid alarming wombats, researchers did not approach the traps during the night until a trap had been 'set off', which triggered a radio transmitter. A radio receiver was used to scan for signals from trap transmitters once each hour through the night. Traps could be left open when not being used to allow animals to freely pass through, but were removed from burrows once the target animals had been caught to avoid further disturbance to wombats.

Common wombat

I constructed a prototype trap for common wombats based on the design used by McIlroy (1976) and those used for the northern hairy-nosed wombat. This trap was short (a little more than the length of a wombat) and had a swinging door through which the wombat entered. The short length was necessary because of the lack of space at the burrow entrance to fit a long trap (such as the double-entrance traps used for the northern hairy-nosed wombat) due to obstacles (trees, logs and rocks) and steep topography. A swinging (as opposed to a sliding 'guillotine' type) door was used because the trap was often partly inserted into the burrow entrance and the roof of the burrow did not permit space for an open sliding door above the trap. This design did not use a trigger device to close the door; instead, the door was simply propped open by a stick which was pushed aside as the wombat entered causing the door to swing shut behind the wombat. Because the door opened inwards (and could not open outwards) the wombat was caught once the door had swung shut behind it (similar to the McIlroy design). At the opposite end of the trap was a sliding door which could be opened to remove or release the animal.

The first cage trap design was constructed of 10 mm diameter steel bars that were spaced apart similar to those used in traps for the northern hairy-nosed wombat, enabling animals to be injected with anaesthetic drug using a hand-held syringe. The first animal I caught in this trap was a large and aggressive wombat that destroyed the trap by bending the 10mm steel bars and caused minor injury to itself. Reaching into the trap to inject the

animal proved to be a dangerous procedure, and the 21-gauge syringe needles (which are routinely used for northern hairy-nosed wombats) would not penetrate the tough rump. The animal was quickly released before causing further injury to itself. The next prototype trap was made of strong fishing trawler netting and was in the form of a large sock with a draw-string at the opening. The open end of the 'sock' was placed over the burrow entrance. The sock was kept open (to form a tunnel) by using three external semi-circular hoops of fencing-wire pushed into the ground and spaced along the length of the sock. Clothes-pegs were used to attach the body of the sock to the hoops. The idea was that once a wombat entered the sock and pushed against it, the draw-string (which was anchored to the ground) would pull the net closed behind the wombat. Since the trap was not made of solid materials it would be unlikely that wombats could injure themselves. I placed this trap over an active burrow for four nights, although no wombats emerged. During this time a number of practical problems with the trap became apparent and the design was abandoned. The main problems were the likelihood of wombats pulling the netting away from where it abutted the soil of the burrow entrance, and the fact that it would not be practical to leave the trap semi-permanently in the burrow entrance.

The final trap design was a cage trap similar to that described above, with the exception that these traps were constructed of 4 mm galvanised weld-mesh, including both doors. A sliding door at the back of the trap enabled animals to be removed or released, and allowed animals to pass freely through if the trap was left 'unused' in the burrow entrance. Wombats that had been caught more than once quickly became trap-wise and could escape by opening either the inward swinging door or lifting up the sliding door. To prevent this I used a twist of wire to secure the sliding door and designed a locking bar which fell down across the swinging door once the animal had entered the trap. The locking bar created its own problems because of the necessity of placing it inside the trap. The first locking bars were made of 6 mm diameter steel and were easily bent by wombats. These were replaced by 10 mm steel and, whilst they were not bent, animals occasionally still escaped by lifting up the locking bar and then pulling the swinging door to open it. For common wombats, a total of 40 traps were constructed; 20 by myself and 20 by an engineering company.

Cage traps were dug into the entrance of the burrow so that there were no gaps between the trap and the soil of the burrow entrance, therefore obliging wombats to enter the trap if they exited the burrow. Common wombats were easily alarmed by unfamiliar noises (particularly heavy footsteps and digging which produce vibrations through the ground) and strange objects at the burrow entrance. For example, digging a trap into the burrow entrance caused wombats to delay their nightly emergence for up to four days. Animals then usually moved to another burrow and the newly trapped burrow was often not used by wombats for several days. To reduce the impact of trapping on normal behaviour and to facilitate the trapping and retrapping of specific individuals, traps were left semi-permanently in burrow entrances. When not being used, both ends of the trap were left open to allow animals to freely pass through. Wombats soon became habituated to the traps, accepting them as part of their burrow entrance. Using this method, wombats could usually be caught the first night that the trap was 'set' on their burrow. Setting a trap 'off' switched on an electric torch (flashlight) that was located near the trap (but pointing away from the trap) and which was attached to a 2 m wooden stake or to a tree. Using this technique, I did not prematurely alarm or disturb wombats by approaching and visually checking traps that had not been set off, and I was quickly alerted when an animal was caught. I was able to monitor the trap lights of some burrows continuously through the night, whereas other burrows required walking a 15-minute circuit and so their lights were checked every 30 to 40 minutes (or more often if I was assisted).

Southern hairy-nosed wombat

I caught southern hairy-nosed wombats at three locations in South Australia: the grazing properties 'Coonaroo East' and 'Stoneyfell', and Brookfield Conservation Park. Wombats on 'Coonaroo East' and 'Stoneyfell' were caught as part of a pilot study investigating body composition and Total Body Water that I conducted in conjunction with Andrew Woolnough (Woolnough *et al.* 1997). These wombats were caught as part of SA NPWS Pest Destruction Permits given to the landholders and the animals were euthanased for this study using intra-cardial injections of sodium pentabarbitone. To capture wombats on 'Coonaroo East', I used cage traps belonging to Brookfield CP

which had a treddle system to trigger shut a spring-assisted door. The traps were dug into the entrances of burrows located in soft alluvial soils associated with a semi-permanent watercourse. Many wombats avoided the traps by digging around or under them, which they were able to easily do in the soft soil.

I used a less intrusive capture method for the energetics work on Brookfield CP because I needed to trap and retrap individuals and because I did not want to disrupt normal behavioural patterns. I selected four active warrens within close proximity to each other and enclosed each within a wire mesh fence, the posts of which were rock-drilled into the limestone substrate. Exit points were cut into the fence where it crossed the well-used paths leading away from the warrens, and at these points traps were placed. Each fenced warren had three to five traps placed around the perimeter, depending upon the size of the warren. The traps belonging to Brookfield CP were unsuited (and too old) for this purpose and so I designed traps similar to those used for common wombats but which were smaller and had a sliding 'guilotine' door made of sheet aluminium instead of a swinging weld-mesh door. I found the sliding 'guilotine' door to be more reliable than the swinging mesh door and less likely to cause injury to captured animals when 'digging' against the aluminium sheet (as opposed to the weld mesh which can result in loss of skin and claws). The trigger mechanism was similar to that used in the northern hairy-nosed wombat traps. A radio transmitter at each warren was switched on when a trap was 'set off'. A radio receiver was used to scan for signals from trap transmitters every half hour through the night.

Wombats on the property 'Stoneyfell' were caught as part of a pilot study of total body water-space. These animals were captured using the 'stunning' method which involves spotlighting an animal at night and firing a projectile (eg .22 caliber supersonic amunition) close above the animal's head. Robertson and Gepp (1982) suggest that the sonic boom of the projectile combined with being dazzled by spotlight makes it difficult for the animal to locate its approaching captors. Stunning was carried out from the trayback of a 4WD vehicle with the help of SA NPWS personnel. Once the shot had been fired two people ran down the edges of the spotlight beam and caught the wombat in a hand-held hoop net.

Behaviour during capture

Reactions to being caught in a trap varied markedly between the wombat species and also varied widely among individuals of the same species, particularly for common wombats. Both of the hairy-nosed species were markedly more docile in the trap than common wombats. Northern hairy-nosed wombats often just sat in the trap when approached, moving only so that their tough hindquarters were facing the perceived threat. Hairy-nosed wombats occasionally attempted to escape, though this was almost invariably by trying to dig rather than more violent activities such as biting the cage and head-butting (as do common wombats), and rarely did these animals injure themselves in the trap. Both of the hairy-nosed species rarely became aggressive and the method I used to anaesthetise them was to quietly approach the trap with a small headlamp and inject them through the mesh with a hand-held syringe.

The behaviour of common wombats during trapping varied from docile to extremely agitated and aggressive. Animals that had been in traps for some length of time (hours instead of minutes) were more likely to become stressed and agitated than those that were anaesthetised soon after capture. Initially, I moved common wombats from the trap into a hessian sack placed over the trap door before anaesthetising them. These animals, which had been physically handled whilst conscious, were always highly agitated in the trap during this handling procedure and were always wary of being re-trapped. Common wombats were often aggressive, uttering deep throaty growls, head-butting, lunging, and attempting to bite (sometimes with success). Animals often suffered minor cuts (usually to lips or gums) and skin loss (pads and noses) from their attempts to dig or bite their way out of the trap. One animal lost a claw (which later regrew), and two others broke a lower incisor level with the gum. Amazingly, when the animals were caught four months later, these teeth were fully regrown (0.5 to 1 cm) with no evidence of overshooting by the top incisors.

Plate 8 Cage trap used to capture common wombats being placed at the entrance to a burrow. The torch was used to signal that a wombat had entered the trap.

Plate 9 Cage trap in a fence placed around a southern hairy-nosed wombat warren. Traps were placed on well-worn pads leading away from warrens. The white electrical cable connected traps to a radio transmitter that signalled a capture.

Plate 10 Fence placed around a northern hairy-nosed wombat burrow. A trap will later be placed on the path through the fence.

Plate 11 Cage trap used to capture northern hairy-nosed wombats. Wombats can enter from either end of the trap, enabling wombats to be caught leaving or entering burrows.

Stress and self-inflicted injury to common wombats was successfully minimised in two ways. Firstly, the length of time that animals spent in traps was minimised as much as possible by using signalling devices such as electric torches or radio-transmitters to signal entrapment. In some cases this time was so short that animals did not appear to be aware that they were caught, since traps were also a normal part of the burrow entrance. Secondly, once animals were caught, I approached the trap quietly using a small headlamp and did not physically touch the animal or the cage before the animal was unconscious. Instead, I maintained a distance of about 1.5 to 2 m and used a blow dart (described below). Despite these measures two animals died as a result of trapping. One animal suffered a single blow to the head whilst attempting to head-butt out of the trap and died instantly. The other irreparably damaged its lower jaw whilst attempting to bite its way out of the trap and I euthanased it with an intra-cardial injection of sodium pentabarbitone (Lethabarb®, Virbac). Non-target wombats were usually not anaesthetised, and instead were immediately released by opening the rear trap door.

3.7.3 Anaesthesia

Wombats were anaesthetised soon after capture with a 1:1 mixture of zolazepam HCL and tiletamine HCL (Zoletil®, Virbac). I used an anaesthetic for two reasons: firstly, to reduce consciousness and hence the stress and possibly the memory of being handled, and secondly, to provide chemical restraint to help prevent self-inflicted injury and to facilitate handling. In all cases the anaesthetic drugs were administered via intra-muscular or intra-peritoneal injection. Common wombats were given the initial injection via a blow-dart. Induction of anaesthesia and recovery were gentle, progressive and uneventful. With few exceptions animals were unconscious within 5 minutes of injection. Details of the anaesthesia procedure, dose rates and recovery are given in Evans *et al.* 1998 (appendix 1).

3.7.4 Blow-Darting

I anaesthetised common wombats whilst still in the trap using a blow dart. The dart is described in detail in Evans and Green 1997 (appendix 2). Briefly, the dart was made from a 2.5 ml syringe (*Terumo* brand or similar) and a cork, and used vinegar

(acetic acid) and baking powder (sodium bicarbonate) to provide the propellant (CO_2) to inject the drug. The blow-pipe was made from a 1 m aluminium tube with an internal diameter of 12 mm. During flight or upon impact with the animal the vinegar comes into contact with the sodium bicarbonate pellet producing CO_2 which pressurises the rear compartment and fully injects the drug within about three seconds. I used the dart to deliver around 1.5 ml of 'Zoletil 100' concentrated at twice the standard strength (equivalent to 150 mg of zolazepam/tiletamine).

3.7.5 Measurement and Marking

Measurements were taken of the length of the body and pes, circumference of the neck, chest and humerous, and total body weight. Animals were given a subjective 'visual body condition' score of between 1 (bad) and 5 (very good). The condition of the incisors and the presence of external parasites and mange were noted. An identification number was tattooed into both ears. The thin ears of the hairy-nosed species enabled the tattoo to be read by placing a light source (torch / flashlight) behind the ear. Reading the tattoo on thick hairy ears of common wombats was less successful, and a better method would have been to tattoo a number on the smooth hairless inner thigh or belly. Although I was not always able to read the tattoo on common wombats, I could usually identify individuals (that were not wearing collars) from a combination of external features such as size, scars, marks, ear rips, incisor chips and cataracts (blue eyes). Weighing was usually done by suspending the wombat (whilst sedated) in a hessian sack from a set of scales that were attached to the middle of a wooden pole (long-handled shovel) supported on the shoulders of two people. When assistance was not available I used a fork in a tree as the other support for the wooden pole.

3.7.6 Capture Results

Trapping success, in terms of captures per number of trap-nights (No. traps x No. nights), was low throughout the study, averaging about five per cent for common and northern hairy-nosed wombats and about 10% for southern hairy-nosed wombats. Low trapping success for common wombats arose because only about one in five 'active' burrows was occupied, and some animals that had been caught more than once were trap-

shy. The total number of captures of common wombats was around 80, most of which were recaptures. The aim of most trapping was to recapture target animals (those wearing collars or that had been injected with isotope). Non-target animals were usually immediately released when caught due to the time and expense (cost of drugs) of anaesthetising, measuring and marking animals, though mainly because of the added disturbance to target animals still down the same burrow. For common wombats, positive identification of an individual usually involved anaesthesia (enabling close inspection of ear tattoos), and therefore the majority of non-target individuals were not identified. This, combined with non-random trapping of different burrows at each site, means that I undoubtedly did not trap or identify all animals at sites. For common wombats, however, trapping and sightings of known individuals compared to those of unidentified individuals over a three year period, indicated that the number of adult wombats at the site was probably around 25. To my knowledge, no pouch young were dropped or lost during trapping and handling.

3.7.7 Collaring

The anatomy and ecology of wombats present serious problems for the attachment of external radio transmitters or other sensors. Collars are easily shed due to the small ears and short muscular neck which is about the same diameter as the head, and collars and harness systems have caused injury to wombats (McIlroy 1976; Taylor 1993; Brown and Taylor 1984; personal observations). These problems are most pronounced for the common wombat because of its relatively larger neck and smaller ears compared to the other species of wombats, and the dense forest understorey that it inhabits. Not suprisingly, researchers have resorted to surgically implanting radio transmitters into the body cavity to avoid the problems of external attachment (Peters and Rose 1979; Brown and Taylor 1984). Surgery and the placement of the transmitter antenna inside the body, however, present their own suite of problems.

I decided that surgery was a last resort, and that placement of the antenna inside the body cavity would probably cause too much attenuation to receive the signal when the animal was down a burrow. I used a number of collar designs before arriving at one which was successful. Details of this collar are given in Evans 1997 (appendix 3).

3.8 HABITAT USE

3.8.1 Radio-tracking

I examined the seasonal use of habitat by common wombats by radio tracking collared individuals. Adults of approximately equal numbers of both sexes were tracked from three fixed-location tracking stations during 'good' (summer) and 'poor' (winter) seasons. I used location data from radio tracking to estimate the size and position of seasonal home ranges and movement patterns of these individuals. These methods are more fully described in Chapter 5.

3.8.2 Burrow use

I examined burrow-use by common wombats at the Riamukka State Forest by radio-tracking wombats at night and following them to burrows, visiting all known burrows during the day to scan for radio signals of collared individuals and using data from trapping records. These methods are described in more detail in Chapter 5.

3.9 ENERGETICS AND ACTIVITY

I measured field metabolic rates (energy expenditure), water turnover rates and body condition of all three species of wombat during 'good' and 'poor' seasons in terms of the availability of food and water and the nutritional content of food. Field metabolic rates were measured using the doubly labelled water technique which involves injecting animals with a small amount of isotopically labelled ('heavy') water (Oxygen-18 and either Tritium or Deuterium). The rates at which these isotopes are lost to the environment are directly related to rates of metabolism and water turnover. These isotopes can also be used to provide an index of body condition. Daily activity levels were recorded using a motion-sensitive data-logging computer attached to collars worn by wombats. Detailed method for measuring water turnover rates and field metabolic rates are given in Chapters 6 and 7, and methods for measuring activty are given in Chapter 5.

3.10 FIELD TRIPS

I spent over 300 days in the field between March 1994 and March 1997. Figure 3.12 shows times spent in the field at the three sites and the major activities involved. Field trips were not divided evenly between the three sites due to the different detail being collected for each wombat species. Most of the field work (240 days) was conducted at the Riamukka SF site. Two field trips were made each to Brookfield CP and Epping Forest NP to collect data on energetics. Field trips to Brookfield CP coincided with the hot dry summer and cool wet winter to enable comparisons to be made between these seasonal extremes and the energetics of southern hairy-nosed wombats. I had also planned to do a similar comparison between the hot wet summer and cool dry winter for the energetics of northern hairy-nosed wombats at Epping Forest. During the first field trip, however, Queensland Department of Environment and Heritage personnel and myself were able to catch only three suitable (adult) animals. Because this small sample size precluded a meaningful seasonal comparison I decided to conduct the second trip during the same season (winter) the following year so that all of the energetics samples were obtained from within one season. Field trips were also made to various locations in the region around Riamukka SF during the begining of the study to assess area for suitability as study sites. Four trips were made to the property 'Seymore' (located about 13 km south of the site) to test trapping and energetics techniques for common wombats. I did not test these techniques at the Riamukka site in case animals easily became trap-shy. A pilot study of the isotope equilibration times and wombat body composition in southern hairy-nosed wombats was conducted by myself and Andrew Woolnough during two weeks in September 1994 on the property 'Goonaroo East' in the Murray Valley region of South Australia. I also spent two days at the 'Porpoise Pool', Coffs Harbour, to test a collar design and to determine isotope equilibration periods using tame captive common wombats.

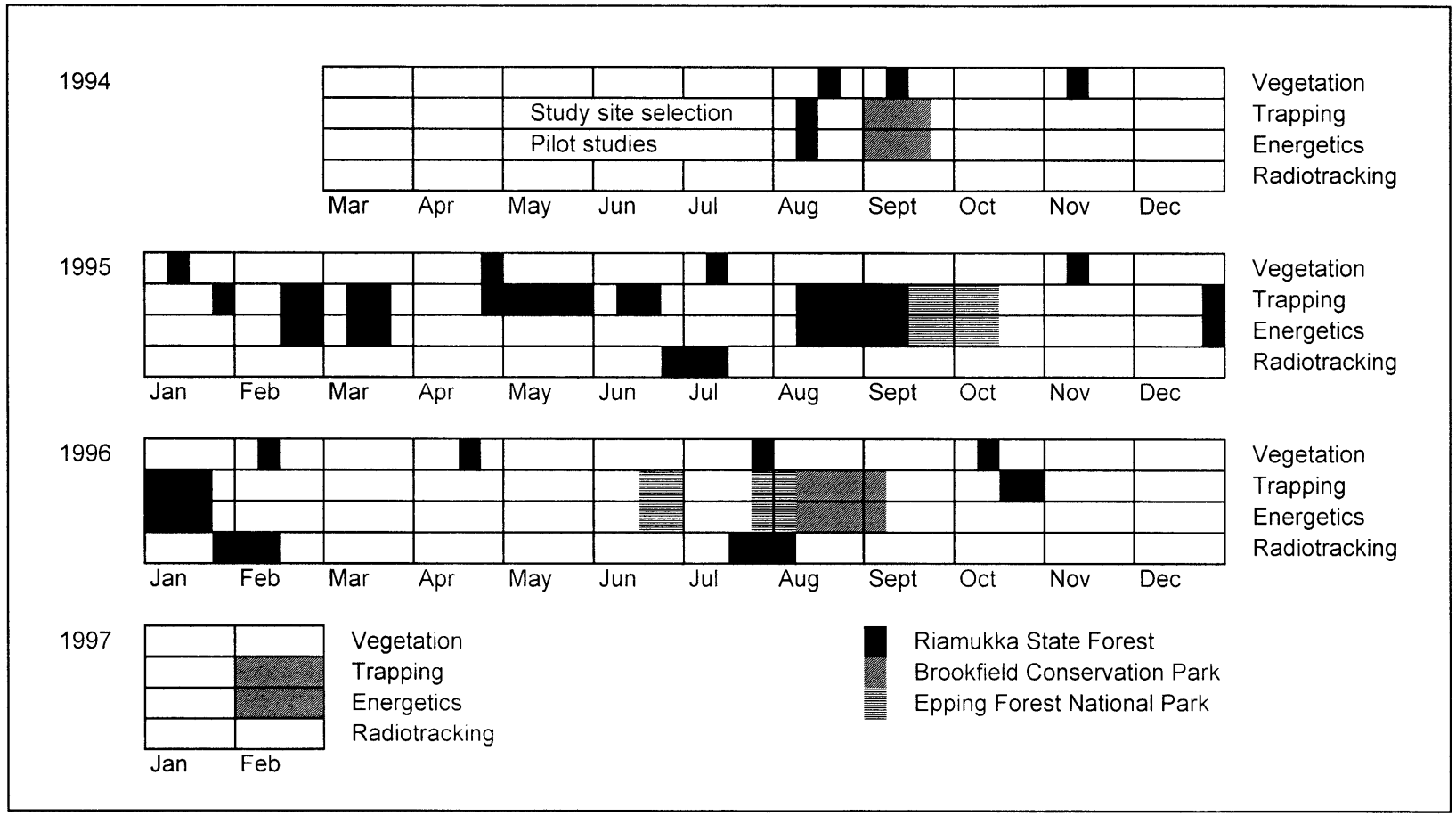

Figure 3.12 Weeks spent in the field at the three sites during the study and major activities involved.

3.11 ANALYSES

Statistical Analyses

Statistical analyses were done using the PC program STATISTIX (Anon. 1990). Unless otherwise stated, means are given with the standard error of the mean (SE). Degrees of freedom for *t*-tests on samples of unequal variances were computed using Satterwaite's approximation (Snedecor and Cochran 1980) and hence are expressed as a decimal number. Bartlett's Test was used to test for homogeneity of variances among more than two groups. Where variances were heterogenous ($P \leq 0.05$), non-parametric Kruskal-Wallis Tests were used, and if significant, these were followed by *post priori* Kruskal-Wallis median tests (Anon. 1990) to locate significant differences among groups. For equal variances between groups ($P > 0.05$), ANOVA was used, and if significant, these were followed by Tukey HSD tests (with Bonferroni corrections to alpha levels where required) to locate significant differences among groups. Linear regressions were calculated using the least squares method. All variables were transformed to approximate normality if necessary prior to parametric tests. Non-parametric tests were used for variables that could not be adequately transformed to approximate normality.

Other Analyses

The PC version of BOTANAL (Tothill *et al.* 1978) was used for the pasture species composition and yield data. Radio-tracking locations and home ranges were analysed using a computer program written by myself. Isotope analyses were conducted at the CSIRO Division of Wildlife and Ecology, Canberra, with the help and supervision of Dr. Brian Green and Keith Newgrain. Most of the plant nutrient analyses were done by Marion Costigan and microscopy analysis of wombat pellets was done by Kate MacGreggor, both at the Department of Ecosystem Management, UNE.