CHAPTER 2

STUDY REGION & SPECIES

The Guy Fawkes River Brumby
~By Bruce Brislane

'The day was hardly dawning when I saw them there one morning,
As they crossed the shallow river in full view,
An old bay mare was guiding as they filed around the siding,
To tread through knee high grass, still wet with dew'...

2.1 Introduction

Before presenting methods, this chapter begins with a description of the Guy Fawkes River National Park region with emphasis placed on the northern sector, particularly the 40 km^2 Paddy's Land plateau and the surrounding drainage, Bob's Creek. Along with the regional setting, a history of human and environmental disturbance is presented to illustrate factors that may influence free-ranging horses in the Park. The focus then moves to a description of the study species, *Equus caballus* (Linneaus, 1758). Resource requirements, social organisation, and population processes are discussed. Research objectives are reviewed, general methods are presented and the thesis proceeds with a description of the study.

2.2 Study Region: Guy Fawkes River National Park

Guy Fawkes River National Park is a vast area of rough and secluded river country located on the eastern edge of the New England Tablelands in NSW (Figure 2.1a). It was established as a National Park in 1972 and is managed by the NSW NPWS. The initial purchase was approximately 32,000 hectares (A. Prior, NSW NPWS pers. comm., May 2002) and in recent years, there have been several extensions. The Park now encompasses 62,371 ha, with an additional 30,000 ha of adjoining land that has recently been purchased but not gazetted. Since the October 2000 helicopter culling operation, there have been continuing efforts by the NPWS to determine numbers, locations and habitats of the remaining horses. Surveillance operations in mid-2002 resulted in an estimate of between 80 and 120 horses distributed in the northern sector of the Park from Bob's Creek flats to the surrounding Paddy's Land plateau (A. Prior, NSW NPWS pers. comm., May 2002). Bob's Creek is where the majority of the Park's remaining horses are assumed to reside during winter when dams are dry and vegetation has been burned. It is thought that horses come up from the river flats mainly in the spring and summer to inhabit the surrounding plateau (B. Nesbitt, NSW NPWS pers. comm., May 2002). After a series of field trips and through communication with the NSW NPWS, current horse activity was confirmed in northern GFRNP. The Bob's Creek gorge system and surrounding Paddy's Land plateau were chosen in consultation with the NSW NPWS to be the region in which to focus the study (Figure 2.1b).

2.2.1 Surrounding Land Tenures

Before the original gazettal of GFRNP, land in that area was either State Forest or freehold land, or was held as leased grazing land or was vacant Crown land. The main body of the Park is now bordered by the Marengo, Mount Hyland, Chaelundi, Glen Nevis, London Bridge and Oakwood State Forests. Also surrounding the Park are leasehold, Crown and freehold land. The newly purchased estate of 30,000 ha comes from former State Forest land, Crown land and leasehold-land tenures (Reid *et al.,* 1996). These areas have previously sustained large amounts of stock grazing and much of the surrounding State Forest and Crown land is currently leased for grazing purposes.

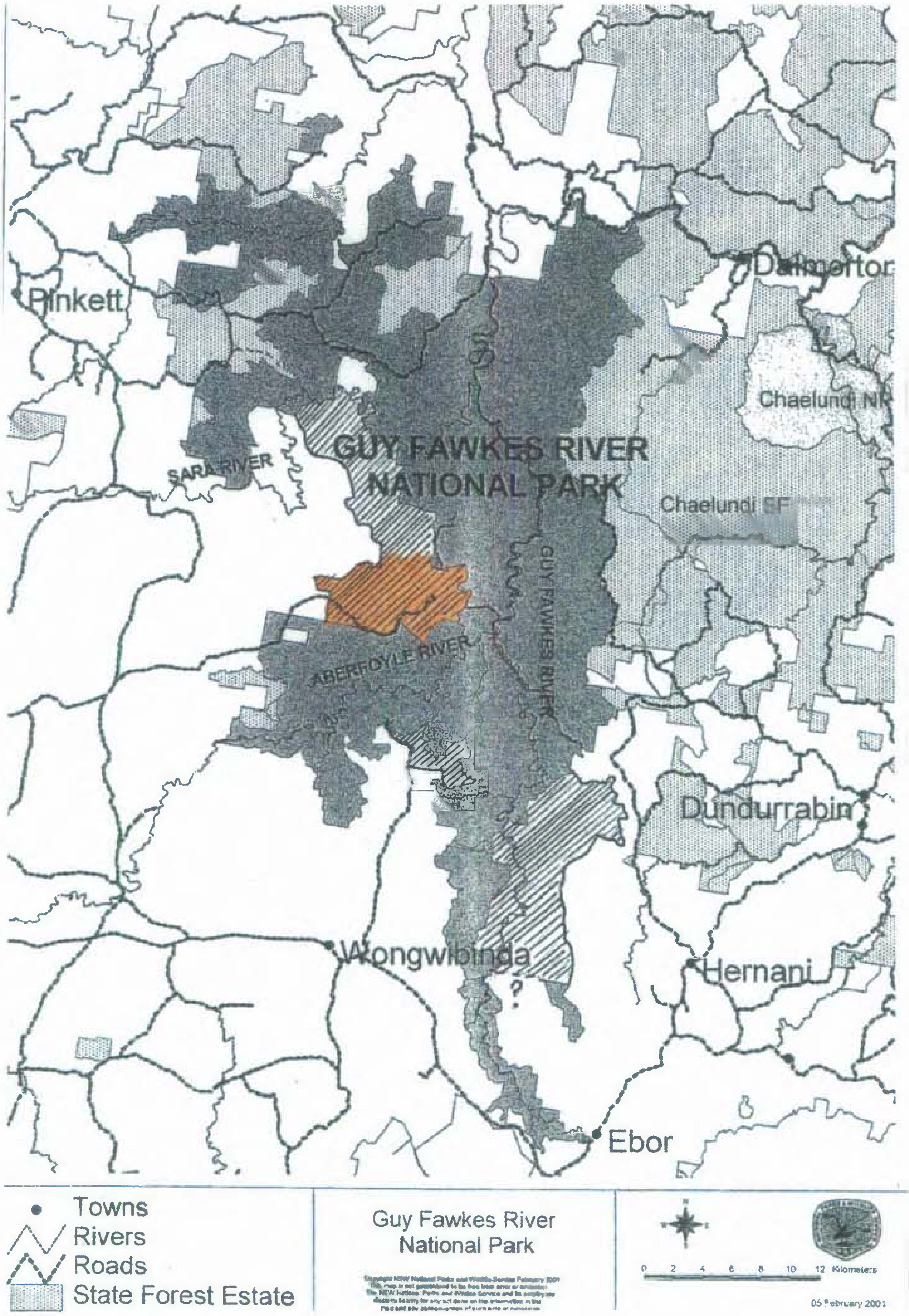

Figure 2.1a Map of Guy Fawkes River National Park with recently purchased estate hatched and study area shown in orange (Adapted from NSW NPWS, 2001).

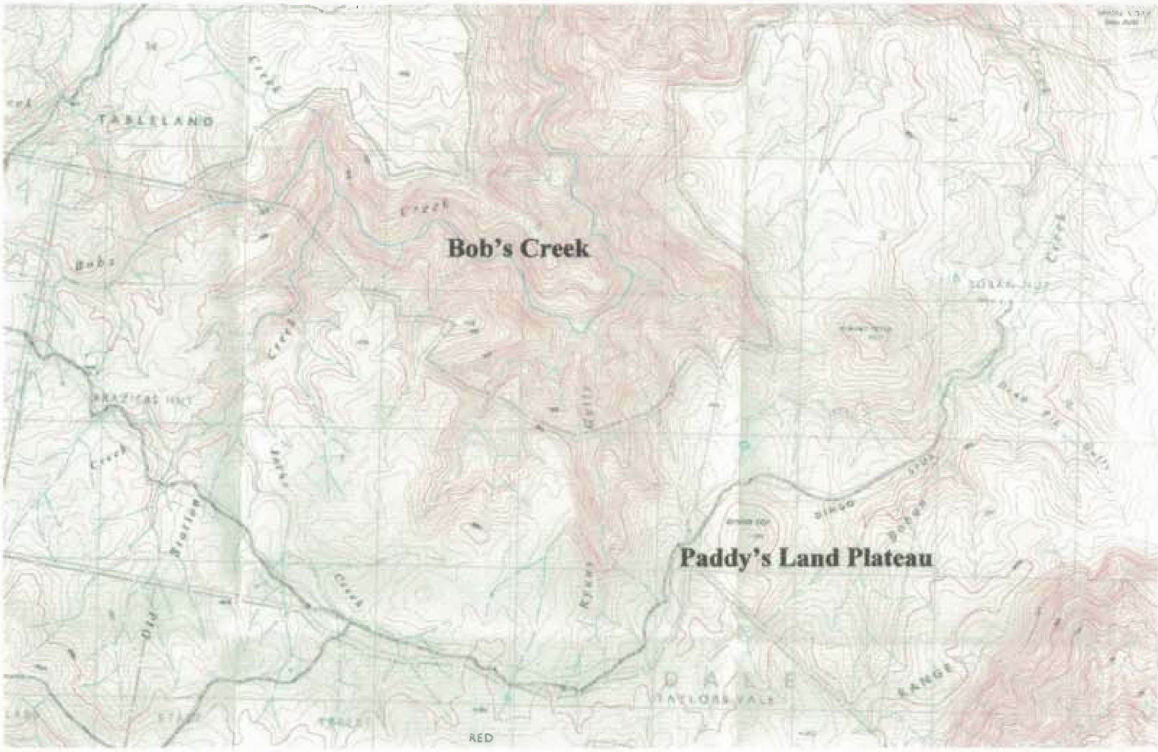

Figure 2.1b Map of Bob's Creek and Paddy's Land plateau, GFRNP (Australia 1:100.000 Topographic Survey Ebor 9337 and Newton Boyd 9338).

2.2.2 Geology

The dominant geographical feature of the Park is the north-south running gorge and valley carved through the tablelands by the Guy Fawkes River (Rose *et al.*, 1999). It is situated in the Clarence River catchment with other deep gorges cut by major tributaries including the Aberfoyle and Sara Rivers. The Park is bisected geologically by the Demon Fault, which occurs along the junction of the two major geological blocks, the Dyamberin block to the west, and the Coffs Harbour block to the east (Reid *et al.*, 1996). The Park is mainly composed of sedimentary rocks with alkaline basalts from the Ebor volcano and intruding granite masses occurring around Chaelundi Mountain and the Boyd River (Muir, 1999). Maps from the NPWS Vegetation Report of GFRNP (Austeco, 1999) were used to display environmental attributes. The soil types derived from the geological blocks include shallow loams, red contrast soils and yellow earths. Slopes are steep in the gorge country ranging around 30° and less than 15° on the plateau. Elevation within the Park ranges from 200 to 1,380 m. Bob's Creek is situated under 500 m and Paddy's Land plateau lies between 600 and 1000 m.

2.2.3 Climate

Situated in the temperate climatic zone, GFRNP experiences variable weather. Elevation influences temperature with the tableland plateau experiencing lower temperatures than the river flats. Positioned in the rain shadow of the elevated western and eastern plateaux, the river gorges are relatively dry and rarely experience frosts or snowfalls. The ridges and high points of the elevated tablelands, on the other hand, experience high rainfalls, frequent frosts and occasional snowfalls in winter (NPWS, 1992 in Reid *et al.*, 1996). The prevailing winds are south-easterly to easterly in summer and westerly to south-westerly in the winter (Reid *et al.*, 1996). The study region has annual rainfall totals varying between 600 mm and 1100 mm per year. Drought is a naturally occurring phenomenon, which happened to create severe conditions on the New England Tablelands during 2000 and again in 2002-2003 (see Figure 2.2). Mean daily temperatures are variable with Bob's Creek ranging from 12 to 17°C and Paddy's Land plateau ranging from 12 to 14°C.

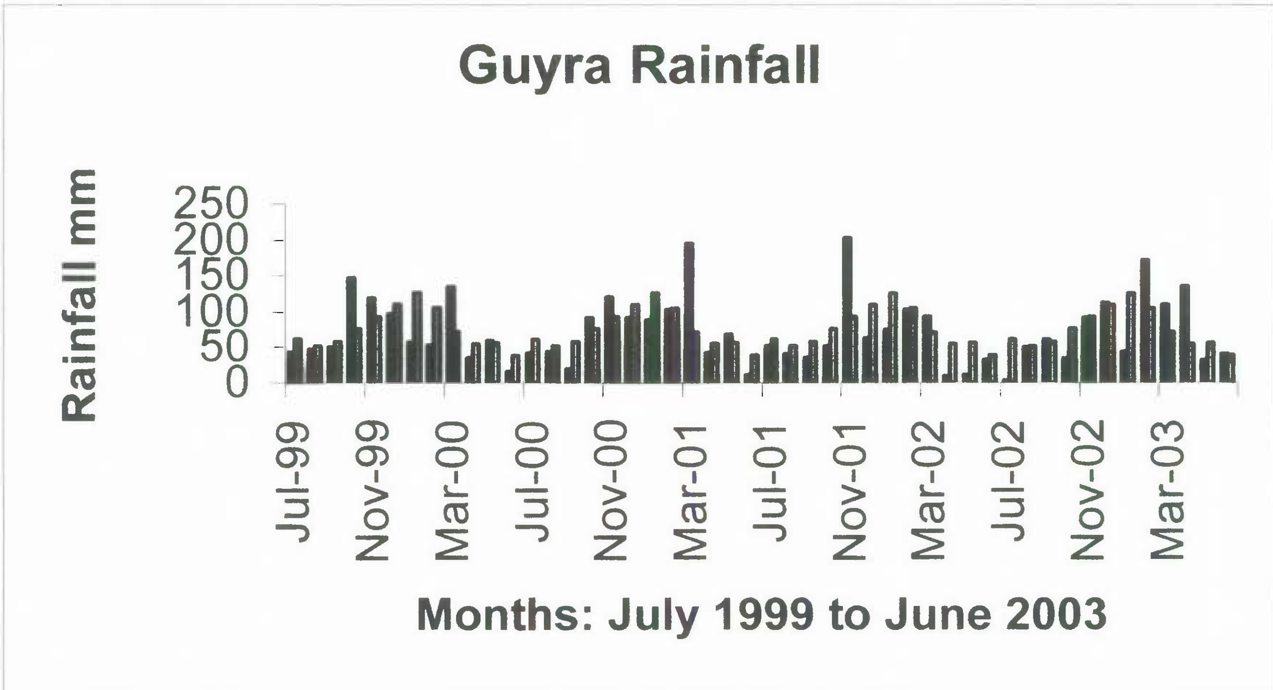

Figure 2.2 Monthly rainfall totals from July 1999 to June 2003, at Guyra Hospital, which is the nearest relevant weather station (Australian Bureau of Meteorology, 2004). The black series represents values for the long-term mean monthly rainfall and the light blue series is the actual rainfall values for each month from July 1999 to June 2003.

2.2.4 Flora

Dramatic changes in topography, geology and rainfall gradients create a mosaic of vegetation types. Abrupt changes in elevation result in climatic variation between the top and the bottom of the gorge systems. This provides an array of plant habitats over a short distance, and consequently a high diversity of plant species and vegetation types (Reid *et al.,* 1996). The Park supports 17 plant species that are listed in schedules one or two of the *NSW Threatened Species Conservation Act TSCA 1995* or are listed on the Rare or Threatened Australian Plants (ROTAP) register (Briggs & Leigh, 1988 in Rose *et al.,* 1999). The latter means they are Rare or Threatened across their entire distribution (NPWS, 1994 in Rose *et al.,* 1999).

The Park occupies an important core position in an extensive belt of high quality, mostly eucalypt-dominated forest (Austeco, 1999). The major vegetation type is dry sclerophyll forest with a number of coastal affinities occurring on the steep gorge slopes and broader valley flats. Areas of dry rainforest, sub-tropical and warm temperate rainforests are found in protected gullies and gorges of south-easterly aspects. On the tablelands above the escarpment, dry and wet sclerophyll forests dominate (Muir, 1999).

Old-growth forests are located in the north-eastern corner of GFR Wilderness around Chaelundi Mountain. Open forests and woodlands dominate the Paddy's Land plateau area. The structural form of Australian vegetation for open forests is medium foliage cover making up the tallest stratum with 30 to 70% cover (Specht, 1970 in Muir, 1999).

To determine which vegetation communities occurred, the NPWS Vegetation Report for GFRNP for use in fire and resource management (Austeco, 1999) was studied. Although Paddy's Land plateau was not included in GFRNP at the time this map was produced in 1999, the surrounding vegetation communities were used as an indication of what might be there. The vegetation community map is shown to demonstrate high variability, not to describe the vegetation communities of the entire park.

The map reveals that four different vegetation communities were found near Bob's Creek and two different vegetation communities occurred near Paddy's Land plateau (Figure 2.3). Each community type occurring in the project area is listed in Table 2.1. Descriptions of each community type are further detailed in Appendix 2.1. Each of these vegetation communities has species of conservation significance (Austeco, 1999).

Field trips were taken to confirm the vegetation of the study region. A discrepancy found between the information from Austeco, 1999, and the vegetation field survey may have arisen because Austeco did not ground-survey the project area. Specimens of nine tree species that were encountered frequently were collected, identified and deposited in the N.C.W. Beadle Herbarium (NE).

The eucalypt species appearing to dominate the woodland plateau was *E. amplifolia* (Cabbage Gum) (L. Copeland, UNE pers. comm., May 2002). Co-dominant species includeded *E. saligna* (Sydney Blue Gum), *E. melliodora* (Yellow Box), *E. mollucana* (Grey Box), *E. caliginosa* (Broad-Leaved Stringybark) and *Angophora subvelutina* (Broad-Leaved Apple). *Corymbia citriodora* (Lemon Scented Gum) also occurred on the plateau. Dominance varied among sites. Tree species dominating the small tree and shrub layer included *Acacia filicifolia* (Fern Leaved wattle) and *Allocasuarina torulosa* (Forest oak).

Table 2.1 GFRNP Vegetation communities description DRF = Dry Rain Forest, DSF = Dry Sclerophyll Forest (Adapted from Austeco, 1999).

Vegetation Community & Study Area	Community Description
Community 1 Bob's Creek	Distribution of DRF *Dendrocnide excelsa* and *Drypetes australasica*
Community 10 Paddy's Land plateau	Distribution of medium DSF *Eucalyptus dorrigoensis*
Community 12 Bob's Creek & Paddy's Land plateau	Distribution of medium DFS *Eucalyptus bridgesiana, E. campanulata, E. caliginosa* and *E, laevopinea*
Community 16 Bob's Creek	Distribution of Medium Moist/DSF *Angophora subvelutina* and *Corymbia intermedia*
Community 20 Bob's Creek	Distribution of medium DSF *Eucalyptus biturbinata, E. campanulata* and *E. laevopinea*

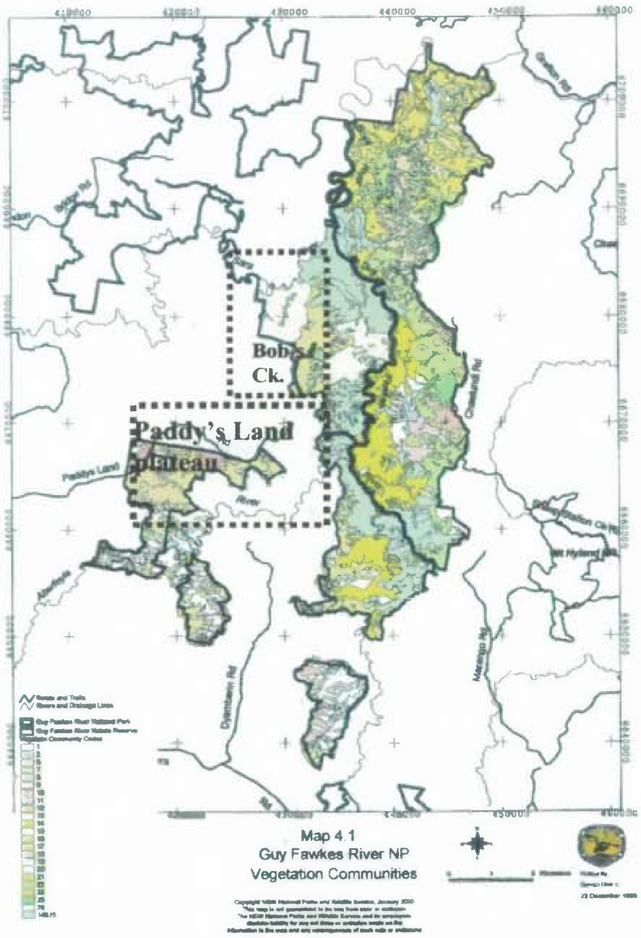

Figure 2.3 Structural vegetation communities map for GFRNP 4.1:61 showing the high habitat variability (Adapted from Austeco, 1999, in which the vegetation communities were identified).

2.2.5 Fauna

The diverse vegetation communities and landform variation of GFRNP provide habitats for a rich native fauna. A preliminary survey recorded over 150 species of birds, 43 species of native mammals, 16 species of frogs and 42 species of reptiles (Muir, 1999). Twenty-five species of fauna listed in schedules one and two of the *NSW TSCA 1995* are either present or likely to be present in GFRNP (Muir, 1999). The mammals occurring in the Park that are listed in schedules one and two of the *TSCA 1995* include: *Phascolarctos cinereus* (Koala), *Petaurus australis* (Yellow-bellied Glider), *Petaurus norfolcensis* (Squirrel Glider), *Dasyurus maculatus* (Spotted-tailed or Tiger Quoll), *Petrogale penicillata* (Brushtail Rock Wallaby), *Aepyprymnus rufescens* (Rufous Bettong), *Macropus parma* (Parma Wallaby), *Falsistrellus tasmaniensis* (Eastern False Pipistrelle), and *Miniopterus australis* (Little Bent-winged Bat) (Muir, 1999).

Endangered bird species present include *Ninox strenua* (Powerful Owl), *Tyto novaehollandiae* (Masked Owl), *Tyto tenebricosa* (Sooty Owl), and *Calyptorhynchus lathami* (Glossy Black Cockatoo). A protected amphibian *Lechriodus fletcheri* (Fletcher's Frog), and a newly discovered lizard *Leiolopisma zia* (Skink), have also been found. Another species of concern, *Maccullochella ikea* (Eastern Freshwater Cod), occurs only in parts of the Clarence River System and the Guy Fawkes River is an important breeding ground for the species (Muir, 1999).

2.2.6 Land-Use History

The GFRNP area has a multiple land-use history. The area served as a main traffic and trade route between coastal and tableland Aboriginal tribes, and Chaelundi Mountain held great significance for the Bundjalung communities as a ceremonial site (Muir, 1999). The tablelands surrounding Guy Fawkes River were first settled by Europeans in the 1830s, and grazing penetrated the gorge country approximately a decade later (Muir, 1999). Few permanent natural water sources were found on the dry sclerophyll plateaus; leading early ranchers to construct dams or stock ponds in what may have been the highest productivity seasonal drainage-line areas. The absolute density of dams was not determined but, Paddy's Land plateau alone has nearly 20 abandoned stock ponds (some dry) in drainage line landscape positions. Thus on this plateau of approximately 40 km^2 most areas are within 2km of a stock pond. A majority of stock ponds now consist of mud, dung and bones from horses and cattle, with no signs of aquatic life (pers. obs. 2002/03). It can be assumed that adjacent grazed plateaus have similar numbers and similar conditions. Permanent natural water sources are located in the surrounding river valleys and include the Guy Fawkes, Aberfoyle, Sara and Boyd Rivers. Semi-permanent water sources include many of the drainage areas flowing into these rivers, some of which are now dry in part because of the hydrologic impact of the stock ponds (Kusler and Opheim 1996).

With the *Forestry Act of 1916*, large areas of land were dedicated as State Forest. Regular harvesting operations and extensive hardwood removal followed. Roads were established during and after the Second World War and logging has occurred where access permitted. The timber industry has exploited the forest resources in GFRNP (Muir, 1999). Certain areas were extensively mined for gold in the middle to late 1880s and mining proposals have been produced as recent as 1993, by Cogar Mining Consultants, in the Sara River area. The proposal failed because of conservation priority, and the area is now protected by the NSW NPWS.

Despite the creation of GFRNP, a long section of reserved Crown land along the eastern bank of the river has been maintained as a Travelling Stock Route (TSR). This Reserve has historic land tenure and runs along a section of the Park northwest of the Corner Camp Fire Trail (A. Prior, NSW NPWS pers. comm., May 2002). Importantly, the Bicentennial Horse Riding Trail (BHRT) also bisects the Park from the north to south, following the TSR along the Guy Fawkes and Boyd Rivers and Macdonald's Spur (Reid *et al.,* 1996). On 14 September 1994, 29,625 ha of the Park were declared a wilderness area (the GFR Wilderness) under the *National Parks and Wildlife Act, 1974* and the *Wilderness Act, 1987* (Rose *et al.,* 1999). Historic tenure of the TSR allows for continued, but limited, use by horses and cattle controlled by drovers, and, where the TSR forms part of the BHRT, by horses and their riders.

2.2.7 Fire Disturbance History

Throughout the history of non-Aboriginal use of the Park, there has been irregular disturbance by wildfire. Early settlers, and more recently local graziers, have employed the practice of burning forested leases to ensure a good source of grass for stock during the winter months (Austeco, 1999). Frequently fires escape into adjacent forested country and remain the most common cause of wildfire in the area (Austeco, 1999).

Naturally ignited wildfire has a long history of association with the vegetation of the Park. Fires are typically ignited by lightning striking the exposed ridges, which support dry or grassy sclerophyll forests. A recorded fire history of the Park began after the 1972 to 1973 fire season and indicates that there have been fire events in almost every fire season since then (NPWS, 1998a in Rose *et al.,* 1999). Fire history records show that before the year 2000, when 60% of the Park burned, most of the northern and western sections of GFRNP had either not burned or had only burnt once since 1974 (Fig.1: 21, Rose *et al.,* 1999). There were medium to high loads of fuel in the study region and medium bushfire potential (Rose *et al.,* 1999). Despite the fact that the Park area had large fires in the mid 1980s and a major fire event in 1994, most of Paddy's Land plateau did not burn (Kitchin, 2001). The plateau area to the north of Paddy's Land Road burned in October 2000, and the area south of Paddy's Land Road was burned during a fuel hazard reduction in May 2001. In October 2002, there were fires around the west and southern sector of the Park (A. Prior, NSW NPWS pers. comm., May 2002).

In the NPWS prescribed burning proposal for GFRNP 1999 to 2003, a summary of recommended fire regimes shows a minimum inter-fire period of 5 years for Bob's Creek and 5 to 30 years in the woodland plateau (Rose *et al.,* 1999). To ensure health and longevity of certain forest ecosystems, it is essential to understand fire regimes and allow natural processes to take place. Research suggests that open forests and woodlands require certain fire regimes to maintain their species composition (Rose *et al.,* 1999). They are predicted to have a decline in biodiversity if there is no fire for more than thirty years. However, if three or more consecutive fires occur less than 5 years apart, or if more than two fires severely scorch the tree canopy in that time, biodiversity declines (Rose *et al.,* 1999). Following a drought year, such as 2002 when this study took place, the potential for fire can increase. Since the plateau burnt recently, the risk of a low-intensity wildfire should be reduced for the next year or 2.

2.3 Study Species: *Equus caballus*

Equus caballus is a member of the family Equidae, which is approximately 60 million years old and represents the culmination of a long evolutionary line specialising in running (Strahan, 1998). Towards the end of the Pliocene, the geological time period that ended 1.8 million years ago, *Equus* is believed to have arisen in North America from the subgenus of *Pliohippus* called *Astrohippus* (Waring, 1983). Dispersal to the Old World via the Bering Land Bridge occurred, and the spread to South America over the Panama Bridge soon followed. *Equus* fossils are abundant in Pleistocene deposits throughout much of North America, Europe, Asia and Africa but are completely absent in Australia (Berman, 1991).

The family Equidae has one extant genus, *Equus*, which is represented by seven extant species. Apart from *E. caballus,* other extant equids include *E. asinus* the donkey or domestic ass, *E. burchelli* the plains zebra, *E. zebra* the mountain zebra, *E. grevyi* the Grevy's zebra, and *E. hemionus* the Asiatic hemione, which is also known as the onager, kulan or kiang (Black, 2000). The true *caballine* horses inhabited Eurasian lowlands and are now represented by two species, the domestic horse and the Przewalski's horse (Waring, 1983). *Equus przewalski* survives in small precarious populations in captivity, and there have been attempts to re-establish the species in their natural habitat (Berman, 1991). The Western Plains Zoo in NSW breeds Przewalski's as does Monarto Zoo in SA. In 1995, they sent seven horses to Mongolia. Three of these were successfully released into the wild (K. Downs, UNE pers. comm., April 2002). Today, *E. burchelli* is the most common truly wild equid, surviving in substantial numbers of around several hundred thousand in Africa. These estimates are still small in comparison to free-ranging and domestic equid populations. The most successful present day equids are the horse and domestic ass, which have been dispersed to almost every continent because of their association with humans (Berman, 1991).

Free-ranging equid populations exist in Ethiopia, Kenya, Southern Sudan to South Africa, South West Africa, Angola, America and Australia and other parts of the world. The largest populations of free-ranging horses inhabit arid areas of the world that have minimal human development and sufficient water availability, such as the Northern Territory. Other populations occur in a range of habitats. The major factor appearing to determine worldwide distribution of free-ranging horses is low occupancy of habitat by humans (Berman, 1991). The previous chapter illustrated that free-ranging horses are well adapted to the highly variable Australian environment and occupy a wide range of habitats over the continent. Adaptability to a range of foods during times when resources are scarce enables free-ranging horses to have a variable ecological niche. Describing their niche is very complex because of interactions between the available resources, and the presence, distribution and abundance of other species (Berger, 1986).

Like other introduced stock, free-ranging horses are ungulates. There are no naturally occurring ungulates found in Australia. Free-ranging horses and other introduced stock flourished, and the absence of natural predators in Australia allowed the populations to increase with no top-down limiting factor aside from human control. Lack of competition from native marsupials in Australia has played an important role in the success of free-ranging horses. Observations of communities of sympatric mammalian herbivores elsewhere have shown that, in general, larger species are able to displace smaller species in any dispute over access to a resource (Payne & Jarman, 1999).

2.3.1 Resource Requirements

Extant equids are grazers and generally weigh between 250 and 450 kg (Berger, 1986). To have a healthy existence, they must obtain 40 different nutrients with water being the most important (Pilliner, 1996). For this reason, they prefer to graze close to a water source where feed is plentiful. With fresh grass containing 80% water, horses will consume a large amount of water through eating fresh herbage (Pilliner, 1996). During the summer months, horses need to drink once per day and in winter, every second day (Dobbie *et al.,* 1993).

Unlike ruminants, which have four-chambered stomachs, equids have monosacculated stomachs with the caecum, rather than the stomach, being the primary site of fermentation (Berman, 1991). Equids eat small amounts at frequent intervals and spend over 12 hours a day grazing (Pilliner, 1996). Their colon is situated on the floor of the gut cavity where fermenting grass adds weight over the centre of gravity. This adaptation enables equids to maintain considerable speeds essential for the avoidance of predators (Berman, 1991). Free-ranging horses do not evenly graze their habitats. Within each environmental setting, preferences are shown for certain plant species while others are avoided (Waring, 1983). Although preference for certain species may be site specific, research shows that free-ranging horse diets are concentrated on graminoids and forbs (Table 2.2). When preferred foods are no longer available, diet items may include roots, buds, fruit, aquatic plants (Dobbie, *et al.,* 1993), and tree bark (pers. obs., 2002, 2003).

Table 2.2 Previous research on free-ranging horse diets.

Principal Diet Species	**Location**	**Source**
Short grasses, preferably *Enneapogon avenaceus* (oat grass)	Northern Territory Australia	Berman & Jarman (1988)
Sitanion hystrix (bottlebrush squirreltail), *Agropyron spicatum* (bluebunch wheatgrass), & *Stipa thurberiana* (Thurber needle grass).	South-eastern Oregon, USA	McInnis & Vavra (1987)
Agropyron smithii, (western wheatgrass), *Carex* spp. (sedges), *Poa* spp. (Bluegrass), *Stipa* spp. (needle grasses)	North Dakota, USA	Irby *et al.* (2001)
Agropyron spp. (wheatgrasses), *Stipa* (needle grasses) & *Carex* spp. (sedges)	Southcentral Wyoming, USA	Crane *et al.* (1997)
Agropyron, Phragmites, Paspalum & Juncus species	Camargue, France	Duncan (1992)

Although free-ranging horses in Australia are able to select from a wide variety of grasses, herbs and shrubs they are capable of walking long distances to locate the most palatable plant species. In central Australia Berman and Jarman (1988) found that free-ranging horses were able to walk up to 50 km from water to feed. As large-bodied caecal digesters with complex dentition, free-ranging horses can maintain themselves on a relatively coarse low-quality diet (Simpson, 1951; Janis, 1976; Bell, 1971 in Black, 2000). They are well adapted to processing tough plant material, and Berger (1986) reported that free-ranging horses tended to exploit habitats containing fibrous vegetation high in cellulose. Their dentition and the enlargement of their colon and caecum are important adaptations of free-ranging horses to a cellulose rich diet (In Berman, 1991). Free-ranging horses can vary the rate of gut clearance and compensate for poor forage by eating more (Black, 2000).

2.3.2 Social Organisation

A society is described as organised when its 'constituent individuals are distributed non-randomly with respect to each other… and when organisation is brought out by behavioural responses of individuals to each other or to their resource environment' (Jarman & Rossiter, 1994). Many factors influence and shape the social system of free-ranging horses. Behaviours and interactions have been recorded as virtually identical among various free-ranging horse populations. However, inter-individual relationships have been shown to differ considerably (Berman, 1991). Linklater's (2000) review showed that 9 studied free-ranging horse populations had similar social organisation although average group size and composition varied within and between populations.

Many authors have attributed differences in free-ranging horse sociality to ecological and environmental factors such as habitat structure, distribution of food and water, and diversity and quality of vegetation (McCort, 1979; Miller, 1979; Moehlman, 1974; Rubenstein, 1981; Woodward, 1979 in Berman, 1991). Body size, feeding style, food-item abundance and dispersion are also important variables to consider (Jarman & Jarman, 1979 in Berman, 1991). Environmental factors such as drought can influence and control social structure and sex ratios of free-ranging horse populations (Berman, 1991). When the food supply is low and water scarce, social units have been shown to decrease in size (Berman, 1991). Bachelors steal mares from harems, and foaling and survival rates are lower. During times of drought, small social groups join together to form large herds at remaining watering points (Dobbie *et al.*, 1993). Large herds also form around watering points when palatable feed is abundant as demonstrated in Chapter 3.

Other authors have attributed differences in free-ranging horse sociality to demographic conditions such as sex ratio and age structure of the population (Rubenstein, 1981 in Berman, 1991). Based on studies of a number of Serengeti ungulate species, Jarman and Jarman (1979) suggested that behaviour relating to reproduction, mainly mother-young associations and males securing mating rights, influenced social organisation. Berman (1991) suggested that short-term environmental differences influenced behaviour related to reproduction in a free-ranging horse population in Central Australia. Reproductive variables have been reported to influence sociality in a number of ungulates including free-ranging horses (Jarman & Jarman, 1979 in Berman, 1991). The environment and demography, especially adult sex ratio and density, can modify competition between animals for resources and mates (Emlen & Oring, 1977 in Linklater, 2000).

Mare groups have been reported to be stable or unstable and have associations without stallions or with multiple stallions (Linklater, 2000). Breeding and social groups were also reported to range widely in number of individuals. Regardless of differences reported, the constancy of social organisation is remarkable (Linklater, 2000). Free-ranging horses around the world appear to conform to certain patterns of social organisation and some characteristics are widespread.

Most horses prefer to remain with companions. They form discrete social groups called bands (Waring, 1983; Berger, 1986; Linklater, 2000). Although some have termed the breeding group as a herd, a more common definition is that a herd is a 'structured social unit made up of bands following similar movement patterns within a common home range' (Miller & Deniston, 1979; Miller, 1983 in Linklater, 2000). Synchronised seasonal movements, over-lapping home ranges, congregation and inter-band hierarchies at water holes provide evidence for the herd structure (Linklater, 2000).

2.3.3 Population Processes

A harem is a group of females who are defended and maintained by a male from other males (Clutton-Brock, 1982 in Linklater, 2000). Some use the term harem to describe just the mare group but most describe harem bands as reproductive social units that commonly consist of a dominant stallion, one to three mares, and their offspring from the past 2 to 3 years. Harem band size is usually less than ten individuals with four or five being most common (Klingel, 1974; Waring, 1976 in Berman, 1991). Harem bands are secure and generally stable breeding units that require reliable resources such as those provided by areas surrounding permanent waterholes (Berman, 1991; Dobbie *et al.,* 1993; Goodloe *et al.,* 2000; Linklater *et al.,* 2000).

2.3.3.1 Dispersal

Dispersal is a feature of all free-ranging horse populations (Linklater, 2000). The age of dispersal is variable and depends on different circumstances. Young males who disperse may remain solitary for months or years before consorting with a female to establish a new band, or they may join with other males in a bachelor band (Waring, 1983). Bachelor bands are formed by individual males that have dispersed from their maternal harem band. Typical bachelor band size has been reported to range from three to five with up to ten individuals in a group (Berman, 1991). These bands are mainly comprised of 2 to 4-year-olds and have been characterised as relatively unstable with frequent changes to their composition. They are more mobile than harem bands and readily occupy areas where water is less reliable. Becoming a harem stallion requires several years of social and physical development, and when bachelor males can acquire mares and create a harem they return to areas where resources are more predictable (Berman, 1991).

Bachelor stallions, as well as juveniles and sub-adults, rarely participate in reproduction. With further development and experience status is altered and the life cycle and dynamic social organisation of horses eventually provide reproductive opportunity to most individuals (Waring, 1983). Young mares that come into oestrus and are ignored by the harem stallion usually disperse from their maternal group to seek attention from other males. Young females tend to join established harems but may remain solitary for some time (Waring, 1983). Juvenile horses sometimes join a mixed-age assemblage of other young horses that have also dispersed from their maternal bands (Waring, 1983). Emigration by adults is often temporary. However, the death or removal of a key group member can cause the band to break up (Waring, 1983).

Established social units are not readily open to admitting outsiders but stallions encourage new mares into harem bands and, in some cases, allow other males to join. Multi-stallion bands have been reported numerous times in the literature (Feist, 1971; Keiper, 1976; Miller, 1979 in Berman, 1991; Goodloe, 2000; Berger, 1986; Linklater, 2000). If the dominant stallion and mares of the band tolerate subordinate males, the latter may become permanent members of the band. Subordinate males commonly participate in herding and defence of the band and are potential heirs to the stallion's position (Waring, 1983).

2.3.3.2 Home Range

Linklater's (2000) examination of free-ranging horse populations revealed that home ranges showed variation within and between populations, and maximum home range size was determined to be 230 km^2 with much smaller core use areas. Bands throughout populations lived in undefended home ranges largely or entirely overlapping with other bands. Home range sizes tended to be largest in arid habitats. Research indicated that free-ranging horses in Central Australia occupied a home range of approximately 70 km^2 with a maximum of 100 km^2 (Dobbie *et al.* 1993). This range size is greater than in areas of the country with higher precipitation. Studies using radiotelemetry have shown that the free-ranging horses of GFRNP have relatively small home ranges from 6 to 28 km^2 (B. Nesbitt, NSW NPWS pers. comm., September 2002). Research indicates that free-ranging horses have a strong attachment to their home range (Linklater, 2000) and are reluctant to leave even during mustering operations (Dobbie *et al.* 1993). Bachelor males occupy the largest living areas while harem bands occupy smaller, more stable, living areas near water sources. Stallions generally form a small fraction of the population (P. Jarman pers. comm. August 2004). Linklater *et al.* (2000) found a significant positive correlation between band size and home range size, where band size increased as home range size increased.

It has been assumed that ungulates defecate at random (Irby, 1981). The assumption that horses defecate at random assists in the determination of habitat-use by assuming that the amount of dung is proportional to time spent in an area. Free-ranging stallions on the other hand tend to limit defecation to certain areas and establish faecal mounds called 'stallion' or 'stud' piles. The piles occur throughout their range and are added to by other stallions and younger males (Waring, 1983).

The piles are used during encounters between stallions as part of antagonistic behaviour (Waring, 1983). The fact that stallions create stud piles suggests that they do not defecate at random and perhaps mark their home ranges with this behaviour.

Although this behaviour seems territorial, free-ranging horses appear to require special environmental and demographic conditions to display true territoriality (Berman, 1991). Territoriality is defence of an area by one individual or group against intrusion by other members of the same species (Keeton, 1972 in Berman, 1991), or is a display of site-specific dominance (Linklater, 2000). Free-ranging horses defend territories using the first broad definition. However, there is debate in the literature over territoriality among equid populations (Berman, 1991; Rubenstein, 1981; Linklater, 2000). Stallions dominance perimeter is associated with the mare group, and dominance is mobile rather than site-specific (Linklater, 2000). Dominant harem stallions defend the breeding advantages that territoriality provides (Berman, 1991) and maintain potential mobile territories, which can become site-specific when the abundance of food and water are unpredictable.

2.3.3.3 Reproductive Ecology

Most adult females regularly participate in reproduction. They are naturally seasonal breeders and come into oestrus during spring, through summer to autumn. Oestrus is the period of sexual solicitation and receptivity, which first occurs between 8 and 24 months of age (Pilliner, 1996). During the breeding season, the oestrus cycle recurs approximately every 3 weeks consisting of 5 to 6 days of oestrus unless the mare conceives. After oestrus approximately 15 days of dioestrum occurs and ovulation tends to occur 24 to 48 hours before the end of the cycle (Waring, 1983).

The average gestation period is 336 days and foaling is concentrated over the spring and summer months. After foaling, mares come into oestrus 5 to 10 days later for 2 to 4 days, which is commonly called 'foal heat' (Pilliner, 1996). In winter, mares go into a prolonged anoestrus, which means there is no cyclical ovarian activity and reproductive physiology becomes almost dormant. This ensures that a foal will not be born too early or late in the year when their chance of survival in the wild would be reduced (Pilliner, 1996). Although mares are capable of foaling every year, the stress from pregnancy and lactation usually results in the raising of one foal every 2 years (Dobbie *et al.,* 1993). Most mares in good condition breed successfully but very few mares in poor condition foal (Berman & Jarman, 1987 in Dobbie *et al.,* 1993). Peak foaling rates have been reported as between 8 and 10 years of age, with gradual reduction to the age of 20, and a sharp decline thereafter (Eberhardt *et al.*, 1982).

Mares are very attentive to the needs and welfare of their offspring. Protection towards neonates is an instinctive trait that tends to relax as the foal develops (Waring, 1983). Mares may spend the majority of the year either pregnant or lactating and so they must devote considerable effort into fulfilling their nutritional requirements (Berger, 1986). Apart from caring for their young, females can be social and form complex relationships with relatives and non-relatives (Berger, 1986).

Mares have been shown to exhibit ephemeral bonding, mutual attachment and preference for each other and for the dominant mare's company (Tyler, 1972 in Waring, 1983).

The intensity of stallion sexual behaviour coincides with the reproductive receptivity of the mares. Libido occurs throughout the year in stallions but the sex drive seems to peak in the spring (Waring, 1983). Harem stallions typically limit their sexual interest to the adult mares. They are generally not sexually motivated by the oestrus displays of fillies, especially their own offspring (Waring, 1983). Stallions will attempt to keep adult mares from straying from the band but make little attempt to retain their own fillies (Collery, 1969 in Dobbie *et al.* 1993). Stallions generally maintain a harem until infertility becomes prevalent. Reproductive rates decrease in stallions over the age of 10 years, and similar to mares, a sharp decrease occurs after 20 years of age (Eberhardt *et al.,* 1982). The harem stallion maintains a protective position and upon approach of other bands or intruders, he herds his band together and defends them.

2.3.3.4 Growth Rates

Human and environmental factors can influence rates of increase in free-ranging horse populations. Maximal reproductive rates are not well established in the literature (Eberhardt *et al.,* 1982). Different environments impose varying costs to individuals, which govern the rates of reproduction. Some free-ranging horse populations have higher reproductive rates than their domestic con-specifics, and the rates of increase regularly surpass those of many native ungulates around the world (Berger, 1986). Berger (1986) showed that reproduction in free-ranging horses exceeds that of domestic horses when he reported an increase greater than 2 ½ times (157%) the original absolute population over a 5 year period in the North American west. The finite rate of increase averaged 31% per year over the study period (Berger, 1986). High fecundity was permitted by very high annual survival rates of adults in the Camargue population of France and allowed a growth rate of 30% per year when unmanaged (Duncan, 1992). Eberhardt *et al.,* (1982) reported that free-ranging horse populations can increase by up to 20% per year when resources are not limiting. Their data indicates that populations experiencing rapid growth occur when foaling and survival rates are high and adult mortality is low.

Not all free-ranging horse populations increase rapidly. On Sable Island off the coast of Nova Scotia, herds fluctuated and rates of increase were lower (Berger, 1986). Age structure of populations can directly influence growth rates. High rates can be expected if the population is concentrated in the 'prime' age classes, 8 to 10 years of age, where reproductive rates are highest and mortality is minimal (Eberhardt *et al.*, 1982). Localised free-ranging horse populations tend to remain approximately half-female and half-male with a birth sex ratio of approximately 1:1 (Waring, 1983). However, there have been reports showing different ratios (Berger, 1986; Goodloe *et al.,* 2000; Rubenstein, 1986).

2.3.3.5 Mortality

Free-ranging horse populations are dynamic and fluctuate in response to human intervention and environmental conditions (McKnight, 1976). Research in the United States suggests that males have a higher death rate than females (Berger, 1986 in Dobbie *et al.*, 1993). This may be attributed to the energy costs and stress involved in obtaining mares and maintaining harems. An average of 20% of members of free-ranging horse populations die each year with the main mortality factors in Australia being human control and drought (Dobbie *et al.*, 1993). Natural mortality in free-ranging Australian horse populations is mainly caused by factors associated with drought such as starvation, thirst, the consumption of poisonous plants and bush fires. Poisonous plants limit the free-ranging horse populations in Western Australia, the Northern Territory, western Queensland and northern South Australia (Dobbie *et al.*, 1993). Horses generally avoid poisonous plants but encounters are common during times when other feed is scarce. Toxic plants in Australia include *Crotalaria* spp., *Indigofera linnaei* and *Swainsona* spp. (Dobbie *et al.*, 1993).

2.3.3.6 Conclusions

Reviewing the resource requirements, reproductive ecology and social biology of free-ranging horses indicates that they are flexible enough to survive under a broad spectrum of ecological conditions. Free-ranging horse populations can increase in Australia with few limiting factors and must be managed for the protection of native species diversity. Issues associated with free-ranging horses in Australia were discussed and the study region and species were described in order to set the scene for the quantitative components of this thesis, which are now proposed.

2.4 General Methods

The first objective of this study was to investigate density, habitat-use and distribution of free-ranging horses on Paddy's Land plateau. Replicated line-transects, opportunistic observations and dung-counting methods were applied to achieve this objective. Transect patrols on foot were used over aerial surveys or radio tracking methods. A literature review, ethical considerations and consultation with supervisors resulted in the selection of transect methods and will be discussed in Chapter 3. The second objective was to analyse the past and present phenomenon of bark-chewing impacts to trees.

To evaluate damage across the woodland plateau, landscape-level and patch-level pilot studies were undertaken followed by formal studies that were implemented at larger scales. Pilot and formal studies employed transect and quadrat methods and are discussed in Chapter 4. English's (2000) recommendation for research on methods for assessing the impacts of free-ranging horses led to the third objective of testing of exclosure methods in Bob's Creek. Exclosure studies were conducted to test the design and applicability of a vegetation-monitoring program to measure the effects of free-ranging horses on the herbaceous vegetation in GFRNP and are discussed in Chapter 5.

2.5 Statistical Treatments

Distance-sampling software (Buckland et al., 1993), Chi-square analysis (Neu *et al.*, 1974) and Statgraphics Plus (Version 2.0, 1996) were used for analyses. Significance of test results are reported in three ways, suggested by Coolican (1990), based on (P) the probability level. Significant results were determined from $0.05 \geq P > 0.01$, highly significant results were determined from $0.01 \geq P > 0.001$, and very highly significant results were determined from $0.001 \geq P$ (Coolican, 1990 in Perry, 1994).

2.6 Limitations

Certain factors encountered during the course of this study may have affected the results. Major variables beyond my control are discussed here. Other limitations are discussed in the chapters where they were encountered. The first major limitation was the drought of 2002. Drought is a natural occurrence but may have influenced seasonal distribution of horses across the plateau and made it difficult to test the possibility of seedling establishment in horse dung without artificial and regular watering, which was not feasible.

Another limitation was presence of cattle in the Park. Cattle have similar resource requirements as horses, which made it difficult to assess impacts of horses alone. This point is further discussed in Section 5.1. The remote location chosen for the exclosure study proved to be a limiting factor as well. NPWS chose the Bob's Creek site for exclosures, because they wanted them to be in a part of the park not used by tourists, but that also made them remote and difficult to access for research purposes. The location proved to be a limitation, which affected the usefulness of the exclosure study. However, the intention was to design and test the applicability of such a study and knowledge can still be gained.

Lastly, many sample sizes obtained in this study were extremely small which led to low expected values in certain analyses. Calculated chi-square statistics may be biased if expected values are very low, and could create an artificially large chi-square value making the probability of a type-1 error greater than *apriori* (Zar, 1974). The only way to reduce error is to increase the sample size (n). Larger samples in this study would have resulted in statistical tests with greater power (Zar, 1974). Sample sizes were very small, and hence made it impossible to make valid comparisons in some cases.

2.7 Period of Study

The NSW NPWS Tallagandra Depot, or 'Perry's Hut' as it is commonly called, is situated on the west area of the plateau and served as a peaceful field-base. Fieldwork was conducted mainly in the spring 2002 and summer 2003 seasons but was spread out over a 12-month period starting in April 2002. The first 6 months were used to explore the study region, examine literature on free-ranging horses and establish aims and objectives. Chapters 1 and 2 were shaped, with intent to develop the research aims, and pilot studies were conducted to assist in the design of formal studies. The next 6 months were used to implement formal studies. Statistical analyses of the data were then conducted, results were written up and this thesis was produced. In addition, a report for the NSW NPWS was prepared. On these foundations, the thesis proceeds with a description of the methods.