CHAPTER 1
INTRODUCTION

1.1 Definitions and purpose

Feral animals are "those that have reverted from domesticity to a wild existence" (McKnight, 1976). They have evolved through two phases of selective pressure: the first prior to domestication and the second requiring adaptation for a domestic state. Feral animals have also evolved or are evolving through a third phase requiring adaptation to living wild, independent of humans once more (Munton et al., 1984).

Just over 200 years ago domestic horses were first **introduced** to Australia by European settlers. Some were released or escaped, formed feral populations and were able to colonise land never before trodden upon by **ungulates** (hard-hoofed animals). They fed upon plant species never before eaten by equids and they flourished. In 1984 there were approximately 206,000 feral horses in the Northern Territory of Australia (Bowman, 1985). This population is approximately four times larger than the feral horse population of North America (McCort, 1984), the continent where the genus *Equus* supposedly first evolved (Simpson, 1951).

The purpose of this thesis is to describe the ecology of feral horses in central Australia and discuss the results in the light of knowledge of feral horses and other ungulates elsewhere. **Ecology** is defined as "the scientific study of the interactions that determine the distribution and abundance of organisms" (Krebs, 1985). Those interactions are also often referred to as the ecology of an organism. The southern half (600,000 km^2) of the Northern Territory of Australia is called **central Australia**.

Resources (vegetation, shade and water), horses themselves and other herbivores (cattle, donkeys, camels, rabbits, and kangaroos), dingoes and humans are all factors that may interact directly or indirectly to determine the distribution and abundance of feral horses in central Australia. Each of these factors receives attention in this thesis. However, to set the scene, this first chapter describes the horse (*E. caballus*) and its closest relatives, as they were, as they are, where they were and where they are.

1.2 Evolution

The evolutionary history of the genus *Equus* has been described in detail by many authors (Evans et al., 1977; Waring, 1983), based mainly on the description by Simpson (1951). The following summary, containing points relevant to this thesis, is included because it is important for understanding present day interactions between feral horses and their environment.

Sixty (or fifty) million years ago in tropical or subtropical conditions, which are typified as having uniform and predictable climate and primary productivity, the first equids appeared (Simpson, 1951; Speed & Etherington, 1952). The oldest fossil equids (*Hyracotherium*) were found in the south of England (Speed & Etherington, 1952) but numerous similar fossils have been found in North America, and the evidence suggests early equid evolution was centred in North America. At that time the British Isles, Eurasia and North America were connected and the first members of the equid family were widespread in the northern hemisphere.

They were 25 to 50 centimetres high at the shoulders, each of their toes (4 front and 3 hind) ended in a separate small hoof; they were relatively specialised for running compared to their ancestors; and judging by tooth characteristics they were all browsers eating succulent leaves, seeds and fruit (Simpson, 1951). Speculation about the ecology of the first equids has been based on similarities between them and small antelope (Klingel, 1972). Perhaps, like most duikers (genus *Cephalophus*), they were forest-dwelling, fed very selectively on a wide range of plant species, using particular plant parts only, and their food items were typically of high nutritive value (Jarman, 1974). Klingel (1972) suggested that they were territorial, similar to the small forest-dwelling antelopes. Some fossil equids possessed a concavity in the nasal bones in front of the eyes indicating that they may have had pre-orbital scent glands for marking territories like many of the antelopes (Klingel, 1972).

During the Miocene epoch the environment became cooler and drier and extensive grassland or savanna replaced the tropical forests. Natural selection probably favoured equids that developed teeth well suited to grazing as opposed to browsing, and grazing equids were widely distributed in North America 10 to 20 million years ago. The Miocene equids show morphological adaptations for open grassy habitat including elongation of the legs by digitigrade foot posture (standing on toes), reduction in the number of toes, carrying weight on a single, central toe protected by a hoof, and limbs specialised for locomotion with a swing action moving only in a fore-and-aft plane. All of these adaptations increase the speed and efficiency of locomotion on dry, hard ground.

About 2 million years ago the first members of the genus *Equus* appeared in North America and spread from North America to Asia, Europe, Africa and South America. Fossil remains are widespread and abundant in Pleistocene deposits (Waring, 1983) but none have been found in Australia. Evidence suggests that during the late Pleistocene wild horses, *E. ferus*, were common on the open plains of Europe, Asia, and North America (Clutton-Brock, 1987). However, at the end of the last ice age their range was very much reduced probably as a result of the spread of forests combined with human predation (according to Clutton-Brock, 1987). In both North and South America equids survived the Ice Age but they have since (about 12,000 years ago) become extinct on both American continents along with many other mammals (Martin, 1970a cited by Moehlman, 1974). *Equus* species survived and diversified in Asia, Europe, and Africa but recently Przewalski's horse (*E. przewalskii*), the quagga (*E. burchelli quagga*), the true Burchell zebra (*E. burchelli burchelli*) and the Atlas wild ass (*E. africanus atlanticus*) have become extinct in the wild (Klingel, 1974). Klingel (1974) wrote "the major threat to free-living equids is, in general, the continuous and increasing competition for food and water with domestic stock. Every year additional areas are claimed by pastoralists, areas which consequently are degraded and eventually will become useless to both wild animals and domestic stock."

Horses were domesticated by humans 2,500 to 5,000 years ago (Clutton-Brock, 1987) and have since become extinct as truly wild animals (Berger, 1986) (i.e. they exist only in domestic or feral states). In the last 50 years the closest relative to the domestic horse, *E. przewalskii*, disappeared from its natural habitat and can now only be found in zoos. The domestic horse (*E. caballus*) is almost cosmopolitan due to human introductions. Feral horses occur in large numbers in North America and Australia (McKnight, 1976; Berger, 1986; Graham et al., 1986) and provide an opportunity for ecologists to study wild caballine horses.

1.3 Perissodactyls and artiodactyls

Horses are included in the mammalian order Perissodactyla. The extant perissodactyls are large herbivores that use hind-gut (caecal) fermentation to aid digestion of plant material. They originated perhaps as early as 60 million years ago and diversified to become the most numerous herbivores during the Eocene. The evolution of ruminant digestion (fore-gut fermentation) in the artiodactyl ungulates is thought to have led to competition and a reduction in the diversity of perissodactyls coinciding with the beginning of the radiation of artiodactyls (Van Soest, 1982). Extinct perissodactyl genera number 152 (Morris, 1965). There are now only 6 surviving genera of perissodactyls comprising 3 families, Equidae (7 species) (Table 1.1), Tapiridae (4 species) and Rhinocerotidae (5 species) (Eisenberg, 1981). Why did perissodactyls all but disappear while the artiodactyls survived and flourished? Possible reasons given include differences in digestive efficiency (Colbert, 1969; Janis, 1976), limb morphology (Romer, 1966;

Table 1.1: Classification of horses and related living equids (Groves 1974).

Subgenus: *Equus*	the horses
Equus ferus	Przewalski's horse - survives only in zoos
Equus caballus	horse - domestic and feral
Subgenus: *Asinus*	the asses, donkey, burro - feral and domestic
Equus kiang	kiang, Tibetan wild ass - wild
Equus hemionus	onager, Asiatic wild ass - wild
Equus africanus	African wild ass - wild
Subgenus: *Hippotigris*	the common zebras
Equus zebra	mountain zebra
Equus burchelli	Burchell's zebra
Subgenus: *Dolichohippus*	
Equus grevyi	Grevy's zebra

Colbert, 1969) and reproductive physiology (Rowlands, 1981). Cifelli (1981) presents evidence that indicates artiodactyls did not cause the disappearance of perissodactyls by competition. Following chapters discuss work conducted to determine the degree of dietary (Chapter 4) and habitat (Chapter 5) overlap between sympatric cattle (an artiodactyl) and feral horses (a perissodactyl).

1.4 Ingestion and digestion

The premolars and molars of the horse (*Equus caballus*) are all molar-like and have surfaces which wear differentially to aid in grinding and rasping. In cross section a horse's tooth has alternate layers of enamel-dentine-enamel-cement. Enamel is harder than cement or dentine, and resists wear, causing it to project a little above the other substances, creating cutting ridges (Hildebrand, 1974). Horses' teeth rise higher in the jaw as the exposed parts wear down, thus maintaining a constant wearing height. The lower jaw is narrower than the upper jaw enabling efficient side-to-side grinding motions (Kohnke, 1979). The jaw, teeth, and lips of horses are well adapted for processing tough (cellulose and silica-rich) plant material.

Olfactory sense is used to determine the palatability of the food item before it is taken into the mouth by sensitive mobile lips and then is torn or cut from the ground by the incisor teeth (Waring, 1983). The front incisors are angled slightly forward to enable close grazing of short grasses. The horse has a relatively small stomach capacity compared to ruminant herbivores of similar size. The horse stomach capacity is approximately 6-8 litres (Kohnke, 1979), only 12% of ox stomach capacity (Colin, 1886; Swenson, 1970 both cited by Robinson & Slade, 1974). This is related to the fact that they eat small amounts in a continual grazing fashion relative to ruminants and, unlike the ox, their stomach is not used as a fermentation chamber. The horse lacks a gall bladder because a continuous, small flow of bile is sufficient. There is no need to store bile because they do not digest a large feed collected in a short time.

The enlargement of the colon and caecum is possibly the most obvious and important adaptation of the horse to a cellulose-rich diet. It allows such indigestible substances to remain in contact with a commensal microbial population for digestion. The colon and caecum are divided into distinct ventral and dorsal regions. The bulk of the colon is situated on the floor of the gut cavity, an appropriate place to carry a mass of fermenting grass as the horse gallops because it adds weight over the centre of gravity. This is a case where a modification for grass digestion has required additional adaptation to maintain speed essential for avoidance of predators.

The fermentation chamber of the horse is situated posterior to the small intestine, unlike the ruminant's which is anterior. It has been commonly assumed that ruminant fermentation is superior to fermentation in the caecum and that ruminants have been able to dominate non-ruminants since the Oligocene because they are more efficient digesters of plant material (Moir, 1968). This assumption arises from the belief that fermentation below the sites of gastric digestion and absorption, as in the horse, may result in fecal loss of most microbes and their products (Van Soest, 1982). However, the opportunity for ruminants to digest the fermented products in their small intestine is offset by the more or less complete fermentation of already digestible feed protein, starch and soluble carbohydrates. These substances contained in food can be digested and absorbed by horses and other non-ruminants before fermentation. I am not convinced that ruminant digestion is more efficient than non-ruminant. Ruminants may have dominated non-ruminants since the Oligocene because their pregastric fermentation could detoxify secondary plant substances (Van Soest, 1982) more readily than hind-gut fermentation of the non-ruminant. This topic is pursued in more detail in Chapter 10.

1.5 Ecological competition between large grazing herbivores

Competition can occur between any two species that use the same resources and live in the same sorts of places (Krebs, 1985). By definition competition between large grazing herbivores for food causes members of one or both species to grow more slowly, leave fewer progeny or be at greater risk of death. Sinclair (1979) found zebra numbers to have decreased when sympatric wildebeest increased and believed this was evidence for the presence of competition between these two species. Alternatively, speculation about competition can be based on studies of diet and habitat overlap (Bell, 1970; Hansen et al., 1977; Jarman & Sinclair, 1979; Salter & Hudson, 1980; Krysl et al., 1984a). However, these studies usually show that coexisting species either live in different habitats, eat different classes of plants or select different parts of the same type of plant. Unfortunately, observing dietary differences between species does not necessarily mean that competition has caused the differences. Neither does observation of differences prove the absence of competition. Nevertheless, by understanding the ecology of large grazing herbivores the potential for competition can be assessed.

Text book examples demonstrating interspecific competition include barnacles, *Paramecium*, diatoms and salamander (Begon et al., 1990) or flour beetles (Krebs, 1985). These animals can be easily manipulated for competition experiments. It would be marvellous to be able to conduct controlled experiments to determine whether there is competition between feral horses and cattle in central Australia. However, if an experimental manipulation of the horse/cattle ratio was conducted the results are likely to be inconclusive. Potential confounding factors are variability in the distribution, timing and amount of rainfall and resultant pasture quality and quantity, heterogeneity of soil, vegetation and landform, and the variability in density of other herbivores (e.g. rabbits) and predators (i.e. dingoes). However, pastoralists need to know whether feral horses compete with cattle in central Australia.

Many stations in central Australia have 1 feral horse for every 3 cattle (Bowman, 1987). Could a pastoralist run 4 cattle instead of 3 by removing the 1 horse? Or are the horses using forage that the cattle never use? How many extra cattle can a manager run or how much better might cattle breed and gain weight when horses are removed? To begin to answer these questions we require a knowledge of the differences between horses and cattle in activity (Chapter 3), diet (Chapter 4) and habitat use (Chapter 5).

1.6 Social organisation

Klingel (1972) originally described two basic patterns of social organisation for horses and their relatives. One is characterised by permanent bonds between adults and no defence of territories. Equids that behave in such a way (horses, Burchell's zebra and Hartmann's zebra) form stable, breeding groups made up of one adult male, one or more adult females and their offspring. Males without any attached females (usually immature males) form relatively unstable bachelor groups. Interestingly the breeding groups have been called either family groups (Klingel, 1982), harem groups (McCort, 1984) or bands (Miller, 1979; Berger, 1986) while the relatively unstable bachelor groups are always called bachelor groups.

The second type of equid social organisation is characterised by no permanent bonding between adults. Groups are temporary and may vary in composition from all male, to all female, female-offspring, or mixed sex groups. Some males are territorial and have sole mating rights over estrous females within their territories. Grevy's zebra and African asses display this type of social organisation (Klingel, 1972).

The picture of equid social organisation drawn by Klingel has turned out to be too simple. Variations to the basic patterns of social organisation have been reported. Harem groups with more than one adult male have often been observed (Feist, 1971; Keiper, 1976; Miller, 1979) and called multiple male and female groups (McCort, 1984) or multiple male bands (Miller, 1979). In Wyoming's Red Desert 23 to 45% of the horse groups identified by Miller (1979) were multiple male and female groups. On Shackleford Banks, an island off the coast of North Carolina "two thirds of the harems maintained well-defined, non-overlapping territories" (Rubenstein, 1981). Rubenstein suggested that "territoriality would exist in all horse populations if the costs associated with maintaining it were offset by large enough benefits."

Papers reviewed by Miller (1979) displayed considerable variation from the basic social organisation set out by Klingel (1972) for asses. In some places males rarely defend territories (Woodward, 1979) and in others single and multiple male harem groups defend territories (McCort, 1979). Many authors have attributed differences in equid social organisation to environmental factors (Woodward, 1979; Moehlman, 1974; McCort, 1979; Miller, 1979; Rubenstein, 1981). Most differences occur between locations but Miller (1979) reported changes in feral horse social organisation during his 3 year study period. Rubenstein (1981) concluded that habitat structure, distribution of food and water, diversity and quality of vegetation, as well as sex ratio and age structure of the population may influence the social system. Instead of the simple, two way, equid social system presented by Klingel (1972) there appears to be a complicated array of variations depending on ecological or demographic conditions.

Hoffmann (1983) conducted a 2-month study of feral horses in central Australia and concluded that their social organisation differed from the generally accepted "normal" pattern of wild horse social organisation. Hoffman's observations indicated that breeding groups were unstable. However, his findings were based on extremely limited data which clearly required verification. In central Australia horses have been feral for a comparatively short time. This combined with unpredictable amount and timing of rainfall, or large size of unrestricted populations may cause social organisation to differ from other areas where feral horses have been studied. In Chapter 6 I present work conducted to describe the social system of central Australian feral horses and in Chapter 10 I present ideas that may simplify our perception of equid social organisation.

1.7 Present equid distribution and status

The Przewalski's horse once inhabited mountainous and steppe habitat in China, Russia and Mongolia (Mohr, 1971; Bokonyi, 1974; Klimov & Orlov, 1982) (Figure 1.1). There were 500 Przewalski's horses held in zoos in 1983, mostly descendants of 11 caught around the turn of the century (Berger, 1986). Some of these are to be used in an attempt to re-establish populations in their natural habitat.

The status of many other wild equids appears precarious; for example, Klingel believed there were only 2,000 to 3,000 Somali wild asses. There are several thousand Asiatic wild asses in six or seven populations (Butler et al. 1986). Klingel (1974) gives estimates of 120 individuals for Cape Mountain zebra, 10,000 for Grevy's and 10,000 for Hartmann's zebra. The most common truly wild equid is the plains zebra which numbers several hundred thousand. These populations are small compared to feral and domestic equid populations (Table 1.2).

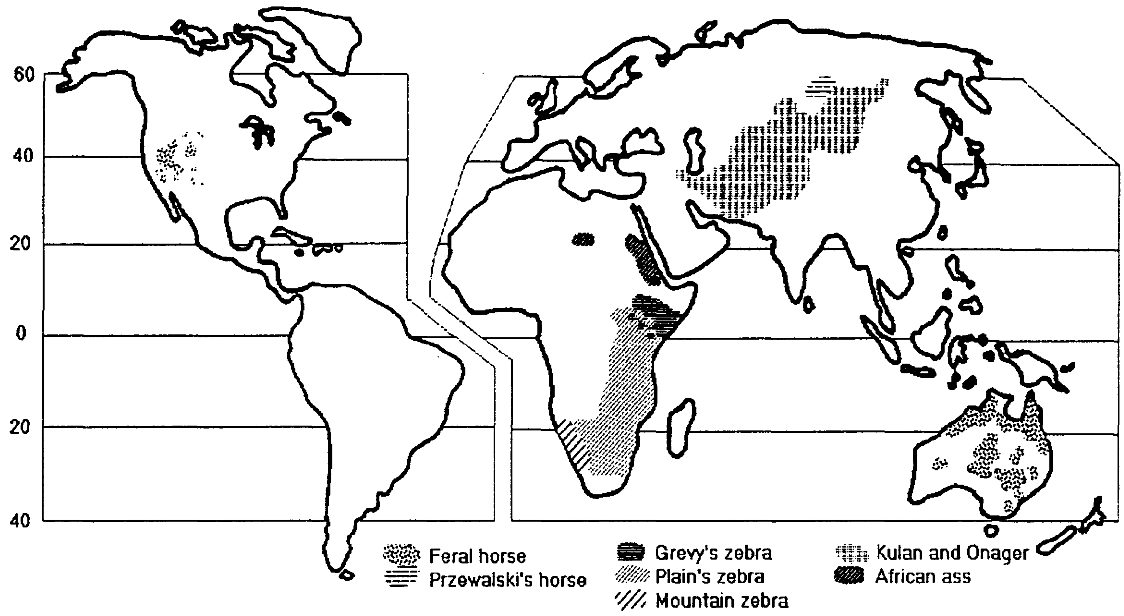


Figure 1.1: The present world-wide distribution of wild equids and feral horses. Adapted from Berger (1986). Przewalski's horse is thought to be extinct in its native habitat.

Table 1.2: Population sizes of extant, wild and feral equids (Klingel, 1974[a]; McKnight, 1976[b]; Berger, 1986[c]; Butler, 1986[d]).

Location	Equid species	Population size
Ethiopia	*E. africanus*	2,000 to 3,000[a]
Kenya	*E. grevyi*	10,000[a]
Southern Sudan to South Africa	*E. burchelli*	>100,000[a]
South-west Africa and Angola	*E. zebra*	10,000[a]
Asia	*E. kiang & hemionus*	Several thousand[d]
USA	*E. caballus*	45,000[c]
USA	*E. asinus*	12,000[c]
Australia	*E. caballus*	>200,000[b]
Australia	*E. asinus*	>100,000[b]

By far the most numerous and widespread present day equids are the horse (*Equus caballus*) and domestic ass (*Equus asinus*) whose survival and dispersal to almost every continent in the world was probably due to their association with humans. "It could well be that the horse...was doomed to extinction by changing climatic and ecological conditions. By chance it was saved by man" (Clutton-Brock, 1987). Once domestication occurred wild horses gradually disappeared. They were presumably absorbed into domestic stock, reduced or eliminated by humans because of their damage to agricultural crops or attempted stealing of domestic mares (Waring, 1983). The remaining wild horses were probably forced to use marginal habitat not only to escape humans but also to avoid competition with domestic stock for food and water.

1.8 Ecology of introduced herbivores

Feral horses in central Australia are an example of a large non-ruminant herbivore introduced by humans on to a continent where they did not evolve. Once established the usual response for an exotic ungulate is an irruption (Leader-Williams, 1988) which follows a well defined sequence of 4 stages (Riney, 1964) having related changes in habitat (Howard, 1964). The process is described clearly by Leader-Williams (1988, pages 21-23). The model was shown to be correct by Caughley (1970) at least for the Himalayan tahr (*Hemitragus jemlahicus*), a goat-like bovid that had been introduced to the South Island of New Zealand. After introduction (stage 1) there is a progressive increase in numbers until the population exceeds the carrying capacity; then (stage 2) extensive areas of vegetation are over utilised and the rate of population increase slows; the population drops (stage 3) below the initial carrying capacity where (stage 4) a degree of stability develops. The population density in stage 4 is lower than the peak density because the habitat has been modified. There has probably been a reduction in the proportion of plant species preferred as food by the ungulate in the plant community.

Jarman and Johnson (1977) found sheep, rabbits, hares and foxes to have generally followed the above stages after introduction to Australia. These authors asked the question "why were resources superabundant for stock when they apparently had not been for kangaroos or wallabies?" They suggested that exotic animals are immune to some substance in the food plants that inhibits the digestive abilities of the native herbivores. Since horses and cattle have different abilities to detoxify plant secondary substances the study of their diet and habitat use allowed me to comment on the hypothesis that plant chemical defences are important factors limiting herbivore populations (Chapters 4 & 10).

There are now more feral horses in Australia than on any other continent. Has this ungulate followed the above stages after introduction? At which stage are they now (see Chapter 10)? Have they changed or are they changing the habitat (see Chapter 8)?

1.9 Feral horse distributions

A description of the distribution of feral horses follows, beginning with a broad, world-wide view, then Australia-wide, the Northern Territory and finally central Australia providing a basis for the rest of the thesis which focuses on intensive work conducted at the level of the central Australia cattle property. Factors that appear to determine the distribution of feral horses are discussed at all levels from world-wide to on-property. The on-property aspects are expanded in later chapters.

a) World-wide distribution

Although there are no truly wild horses left in the world (Berger, 1986) horses have escaped domesticity or were released and reverted to a wild condition. The end of cavalry and increased mechanisation of stock-work, transport and traction made horses redundant in many places and large numbers were left to roam free. The term feral is used to describe these wild horses whose ancestors were once domestic (Berger, 1986). There are now sizeable populations of feral horses in arid areas of Australia and North America (McKnight, 1976; Berger, 1986; Graham et al., 1986). Although domestication may have saved horses from extinction 2,500 to 5,000 years ago (Clutton-Brock, 1987) feral horses appear to be well adapted to survive in parts of present day Australia and North America. In fact a major problem for both Australians and North Americans is management to restrict the size of feral horse populations. Healthy free-ranging but managed populations of horses inhabit parts of England, France and Japan illustrating their ability to flourish under a diverse range of conditions. Table 1.3 shows the range of densities of feral and free-ranging horse populations that have been studied throughout the world and Figure 1.1 shows the world-wide distribution of wild equids and feral horses.

The largest populations of feral horses inhabit arid areas of the world that have low human density but with sufficient surface water for drinking. Other feral horses occur in a range of habitats from small oceanic islands to alpine forests. But the major factor that appears to determine the world-wide distribution of feral horses is the low value of the habitat to humans.

b) Australia-wide distribution

Horses arrived in Australia with the first European settlers on the east coast in 1788. These domestic horses escaped from or were released by drovers and settlers and quickly reverted to a wild condition. By the 1830s "bush horses" were plentiful in the hills around Sydney and as pastoral settlement spread to the north, west and south, uncontrolled horses began to appear in those areas as well (McKnight, 1976). They had probably reached the Northern Territory by the 1870s (Letts, 1964) and have inhabited central Australia, the location of this study, for at least 100 years.

McKnight (1976) described the distribution and abundance of feral horses in Australia using results of a questionnaire/interview survey. The survey was initiated in 1966 and followed up in 1971. Four thousand questionnaires were posted out and 1,300 were returned with useful information.

Table 1.3: Density of feral horse populations and free-ranging but managed horse populations in study areas throughout the world.

Location	Density of horses (/km²)	Study area (km²)	Reference
New Forest (England)	13.9*	180	Tyler (1972)
Withypool Common (England)	5.5*	8	Gates (1979)
Camargue (France)	27.0*	3	Boy and Duncan (1979), Duncan et al. (1984)
Shackleford Island	11.0	10	Rubenstein (1981)
Sable Island	6.3	38	Rubenstein (1981)
Assateague Island	2.2	90	Keiper (1976)
Western Alberta (Canada)	1.0	200	Salter and Hudson (1979,1980)
Pryor Mountain (USA)	2.0	113	Rubenstein (1981)
Oregon Beaty's Butte (USA)	0.2*	1769	Eberhardt et al. (1982)
Oregon Jackie's Butte (USA)	0.5*	316	Eberhardt et al. (1982)
Western Nevada Pah Rah Mustang Area (USA)	0.8	745	Siniff et al. (1986)
Grand Canyon (USA)	0.2	390	Rubenstein (1981)
Granite Range Nevada (USA)	0.3	500	Berger (1983)
Wyoming Red Desert (USA)	0.1	737	Miller (1979)
The Garden station (central Australia)	1.2-0.7*	2113	Chapter 5 this thesis

* Information provided indicating management of population size by humans.

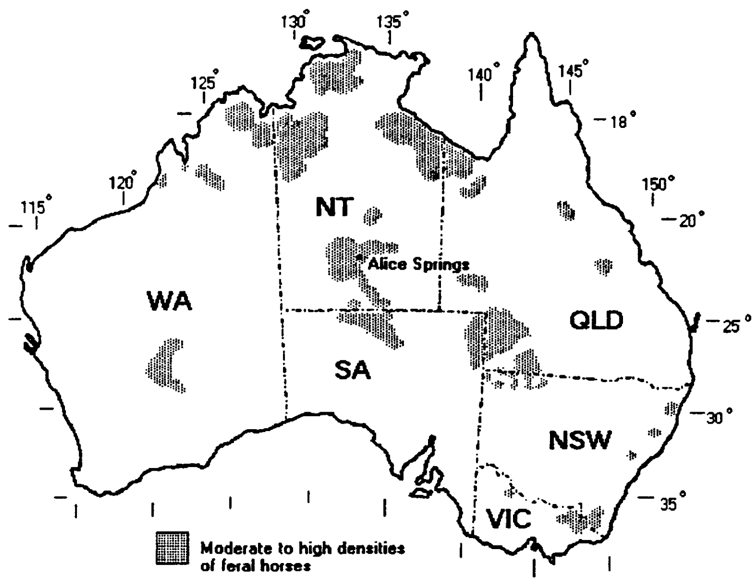


Figure 1.2: Distribution of feral horses in Australia from NT aerial survey (Graham et al., 1982a, 1982b and 1986), WA questionnaire (Campbell, 1989), and the questionnaire survey by McKnight (1976).

Feral horses were reported in most of the extensive cattle-raising districts of Australia (Figure 1.2). Factors that appeared to limit the Australia-wide range were:

- deserts and lack of water
- poisonous plants that cause Walkabout or Kimberley disease, and
- intensive pastoral management.

McKnight's informants reported that feral horse populations increase in good (high rainfall) seasons and decline during times of drought. Control exercises by shooting or trapping if carried out in an organised way can cause significant decreases or occasionally even eliminate the feral population (McKnight, 1976). McKnight's survey indicated that there were between 128,000 and 205,000 feral horses in Australia at that time (Table 1.4).

Aerial surveys conducted by the Conservation Commission of the Northern Territory (1981/1984) produced an estimate (206,000) (Bowman, 1985) which was 5 times McKnight's minimum estimate (40,000) (McKnight, 1976) for the Northern Territory feral horse population. The possibility that the population has increased by 15 to 20% per

Table 1.4: Feral horse populations of Australian states, based on a questionnaire/interview survey (McKnight, 1976). The survey was initiated in 1966 and followed up in 1971.

State or Territory	Minimum	Maximum
Northern Territory	40,000	60,000
Queensland	40,000	60,000
Western Australia	30,000	50,000
South Australia	10,000	20,000
New South Wales	5,000	10,000
Victoria	3,000	5,000
Tasmania	0	0
Australia total	128,000	205,000

year since 1971 can not be ruled out. In fact, there were 9 years with above average rainfall between 1971 and 1984 (Figure 1.3) promoting pasture growth which may have been sufficient to sustain rapid increase in the feral horse population (Chapter 7). However, it is also likely that McKnight's figure was an underestimate.

If McKnight's estimates were consistent across state borders, and the aerial survey results for the Northern Territory are accurate, then the total feral horse population of Australia could be over 640,000 (5 times McKnight's minimum estimate). This estimate of course needs verification by similar aerial surveys of other states.

c) Northern Territory

The aerial surveys of feral horses conducted by the Conservation Commission of the Northern Territory in 1984 (Bowman, 1985; Graham et al., 1986), combined with data obtained during surveys (both flown in 1981) of buffalos (Graham et al., 1982a) and donkeys (Graham et al., 1982b), give us a view of the Territory-wide distribution and

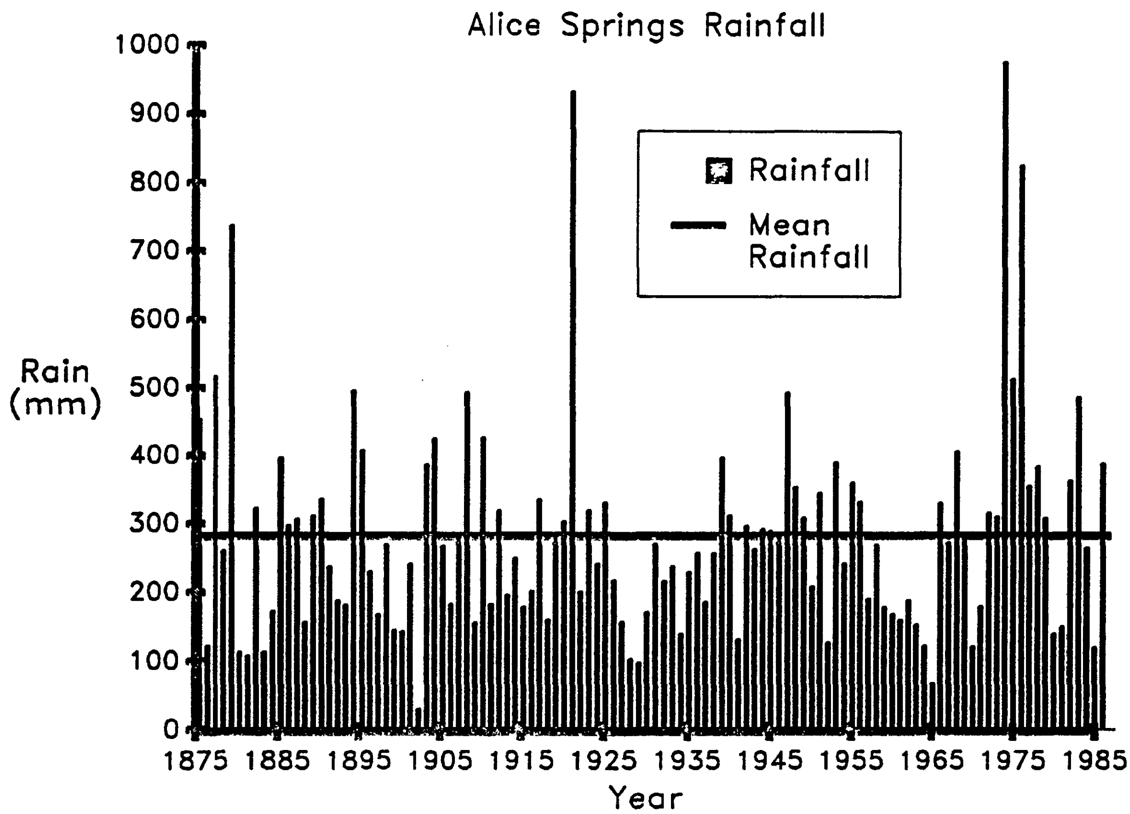


Figure 1.3: Rainfall for Alice Springs from Bureau of Meteorology records (Sep. 1875 to Aug. 1987) (e.g. 1925 indicates 1925/26). Shown are totals for rain years (Sep. to Aug.) because rain is more likely to fall in summer.

abundance of feral horses. Large populations of feral horses were found in the Darwin region (Top End), the Gulf region, Victoria River District (VRD) and the Alice Springs District (Table 1.5). There are few, if any, in the drier areas (the Simpson and Tanami deserts), nor are there many on the Barkly Tablelands (Graham et al., 1986). Factors that appear to limit the distribution of horses in the Northern Territory are:

- deserts and lack of water, and
- the more intense management of the Barkly Tablelands perhaps aided by flat country and the lack of natural watering points.

There was considerable variation in the mean densities for the parts (strata) of the aerial surveys (Table 1.6). For the VRD densities ranged from 0.1 to 0.6 horses/km^2, and

Table 1.5: Estimated populations of horses and cattle in areas of the Northern Territory (834,786 km^2), from 4 aerial surveys (Bowman, 1985; Graham et al., 1986).

SURVEY	FLOWN	ESTIMATE		DENSITY (/km^2)		C/H
		HORSES	CATTLE	HORSES (H)	CATTLE (C)	
Top End	1981	39,000[a]	241,000	0.22	1.43	6
VRD	1981	55,000	534,000	0.49	4.79	10
Alice	1984	82,000	415,000	0.21	1.07	5
Gulf	1984	30,000	153,000	0.19	0.94	5
TOTAL[b]		206,000	1,343,000			7

[a] The figure given in the report by Graham et al. (1982b) was uncorrected. Bowman (1985) used a correction factor of 1.6 which was derived for horse counts using data from the Victoria River District (VRD) survey (Graham et al., 1982a).
[b]Totals do not include cattle and horses from the Barkly Tablelands.

Table 1.6: Estimated horse and cattle populations and number of cattle per horse for the four survey strata (Alice Springs Survey, 2 April to 4 May 1984) (Bowman, 1985; Graham et al., 1986).

STRATUM	MEAN DENSITY (animals/km^2)		MEAN ESTIMATE		RATIO
	HORSES	CATTLE	HORSES (H)	CATTLE (C)	C/H
1-Alice Springs	0.39	1.45	54,772	202,363	4
2-Tennant Creek	0.19	1.03	24,230	134,704	6
3-Simpson Desert	0.00	0.16	0	12,782	∞
4-Manners Creek	0.07	1.74	3,030	64,649	21
ALL MERGED			82,032	414,498	5

for the Alice Springs District, from 0 horses/km^2 in the Simpson Desert to 0.4 horses/km^2 in the Alice Springs stratum. The Alice Springs District survey was chosen by Bowman (1985) to study relationships between environmental factors, horses and cattle.

d) Alice Springs District

In the area of the Northern Territory south of Tennant Creek there were approximately 82,000 feral horses most of which inhabited the mountainous areas and areas along the Finke River (Graham et al., 1986). Bowman (1985) analysed the Alice Springs aerial survey data in order to:

- investigate the relationships between environmental factors, horses and cattle; and
- identify areas where horses and cattle may be competing (i.e. where they occur together).

The survey sampled 387,686 km^2 encompassing most of the pastoral leases of the Petermann, Sandover, and Tennant Creek sub-regions as well as the Simpson Desert. The region was divided into 4 strata based mainly on logistical criteria (flying time, fuelling stops, etc.). However, these strata were expected to reflect broadly differing horse densities. Ninety eight percent of the horses and 93% of cattle occurred in the Alice Springs (Stratum 1) and Tennant Creek (Stratum 2) strata. The Simpson desert (Stratum 3) and the Manners Creek (Stratum 4) strata were excluded from most of the analyses.

Six hundred and sixteen 20x20 km square grid cells were rated for eight environmental types by the front right observer during the survey, using a three-rank system: much, little, and trace. The environmental types included sand plain spinifex (desert), sand dune spinifex (desert), spinifex hills (rugged and rocky), grassy hills, scrubby hills, grassy plains, scrubby plains, gibber plains, and salt lakes. Spinifex genera (*Triodia* and *Plectrachne*) are tough, spiky grasses well adapted to dry, infertile conditions and are unpalatable to grazing animals.

Watering point information was collected for strata 1 and 2 using property maps to distinguish between controlled (bores and dams) and unmanaged watering points (other dams and natural waterholes). The categories used were:

1) bores within 5 km of the flight-line,
2) dams within 5 km of the flight-line,
3) waterholes within 5 km of the flight-line,
4) bores within the whole cell,
5) dams within the whole cell and
6) natural waterholes within the whole cell.

Analyses of the Alice Springs District aerial survey data by Bowman (1985) showed that numbers of both horses and cattle are likely to be low in areas of sand dune and sand plain spinifex. In areas of spinifex hills and scrubby hills numbers of horses are generally high and cattle numbers low. Horse numbers tended to be low and cattle numbers high in areas of grassy plains. There was no significant correlation between horse and cattle occurrence using all data from strata 1 and 2. There was, however, a significant positive correlation between horses and cattle for non-hilly country. Horses tended to be found in high numbers near natural waterholes or dams, whereas cattle appear to be most common in areas which have bores or dams (Bowman, 1985). I must emphasise that these relationships applied at the time of the survey and may not be persistent.

Factors that appear to influence the distribution and abundance of horses in the Alice Springs District include:

- water (presence, absence and type of watering point),
- terrain (presence or absence of hills),
- vegetation, and
- management (difficult in hilly areas which usually have abundant natural watering points).

All these factors interact and probably vary in importance for different areas making it difficult to pinpoint the most important factor. Generally speaking feral horses in central

Australia appear to be most abundant in rugged areas which have many natural watering points. These areas are the most difficult to manage, consequently mustering and culling of horses is costly, resulting in less control of horse populations in mountainous areas. Horses may also have a preference for the food, shelter or soil of the hills over that of the flat country. Poisonous plants (e.g. *Indigofera linnaei* and *Swainsona* spp.) grow mainly on plains and may help suppress horse numbers in some areas. Detailed work at the property level was required to verify the importance of these factors as determinants of the distribution of feral horses (Chapters 4 & 5).

e) On-property

The aerial survey of the Alice Springs District (Graham et al., 1986) indicated that at least some properties in central Australia have more than 1 feral horse to every 4 cattle. The economic report by Bowman (1987) gives the pastoralists' estimates of horse numbers per station in central Australia. Eight percent of the stations surveyed by Bowman were reported by the pastoralist to have more than 2,000 feral horses. The mean size of central Australian cattle stations (n=38) surveyed was 3,390km^2 with 5,400 cattle and 1,200 feral horses. Fifty percent of the landholders interviewed by Bowman considered feral horses as a problem. Damage to fences and competition with cattle for feed were identified as the most important factors. Inferences about the potential for competition are made in Chapter 5 and 10.

Data from the relatively coarse-grained aerial survey were collected over a large area (388,000 km^2), and cannot be confidently used to draw conclusions on distribution and abundance at the level of the property. The Garden station was surveyed from the air on three occasions, May 1986, April 1988 and October 1988, at a finer grain (5 km-spaced transects) than the survey of the Alice Springs District (20 km-spaced transects). Intense ground-based sampling to determine habitat use of both feral horses and cattle were conducted on The Garden station. The methods used for aerial and ground-based sampling on The Garden station are presented in Chapter 2 and the results appear throughout the thesis but particularly in Chapters 5 and 7.

1.10 Previous research

There has been a proliferation of studies on the ecology of wild, free-ranging and feral equids during the last 20 years. Significant research has been conducted in Africa, North America, Asia and Europe. Initially zebras (Klingel, 1965, 1969) received attention, followed by free-ranging but managed ponies in Britain (Tyler, 1969, 1972). Then during the 1970s and early 1980s feral horses and burros were examined in North America by numerous workers (Feist, 1971; Welsh, 1973; Moehlman, 1974; Rubenstein, 1981; Miller, 1983; Berger, 1986). Duncan (1980) investigated the Camargue horses in France and Kaseda et al. (1984) studied free-ranging horses in Japan. Recent comprehensive accounts are to be found in books by Waring (1983) and Berger (1986). However, little is known about the ecology of feral horses in Australia in spite of the fact that Australia has more feral horses than any other continent (McKnight, 1976; Berger, 1986).

McKnight (1976) estimated the feral horse population of the Northern Territory to be about 50,000 based on a questionnaire/interview survey, initiated in 1966 and followed up in 1971. In 1981 aerial survey of the Top End and Victoria River District of the Northern Territory were conducted primarily to count buffalo and donkeys. These surveys indicated that there were 94,000 feral horses in these two areas. Clearly, as mentioned in section 1.9..b), there were far more feral horses in the Northern Territory, in the early 1980s than estimated by McKnight in the late 1960s to early 1970s.

In 1984, amidst growing concerns for the environment and the cattle industry in areas densely populated by feral horses, the Conservation Commission of the Northern Territory (CCNT) on behalf of the Feral Animals Committee (FAC) began a programme of research incorporating;

1) aerial survey of the Alice Springs and Gulf regions,
2) an intensive study of ecology and environmental impact,
3) the economics of management, and,
4) investigation of movement patterns, home range characteristics and harvest methods.

The CCNT contracted the University of New England which in turn awarded me a scholarship to conduct research into the ecology and environmental impact of feral horses in central Australia (1984-86). Subsequently, I worked for the University, then as an independent consultant, on a project to improve methods of management by increasing our understanding of movement patterns, home range characteristics and other behaviour relevant to harvest or control methods (1988-89). This thesis utilises data collected during these projects. The type of data collected and the intensity of sampling were constrained somewhat by the needs of the CCNT to obtain information directly relevant to management. How the information contained in this thesis and other reports (Berman & Jarman, 1987, 1988; Bowman, 1987; Dobbie & Berman, 1990) can be used to improve methods for management is discussed in Chapter 9.

1.11 Aims of thesis

I aim to describe the ecology of feral horses in central Australia by answering aspects of the following questions in regard to my study animal and area.

Chapter 3	How do feral horses spend their time?
Chapter 4	What resources do feral horses and cattle require and which factors influence these resources and their use?
Chapter 5	What influences the distribution and abundance of feral horses?
Chapter 6	What is the size and composition of groups of feral horses, and how do these parameters vary?
Chapter 7	Which measurable parameters are important for predicting changes in feral horse populations?
Chapter 8	Are feral horses having a measurable impact on the environment and how can the impacts of horses and cattle be distinguished?
Chapter 9	How can my studies improve management of feral horses in central Australia?
Chapter 10	How do central Australian horses compare to ungulates elsewhere in the world?

1.12 Structure of thesis

Chapter 2 describes the study area, study animals, materials and methods. A short summary of methods is included in each of the following chapters to refresh the readers memory. Also methods that apply specifically to any one chapter may be included in that chapter's methods section. Chapter 2 is divided into two sections; the first describes the study areas and the second describes data collection methods. Chapters 3 to 7 present results and discussion of studies on The Gardens station and Chapter 8 is based on work conducted in the Kings Canyon area. In Chapter 9 I combine a case study of management of feral horses on The Garden station with knowledge from all the chapters of my thesis to show how this work can be used to improve methods of management of feral horses in central Australia. Finally, Chapter 10 brings together key findings from each of the preceding chapters and discusses this work in the light of the available information and theory on equids and other ungulates.

CHAPTER 2
STUDY AREA AND METHODS

2.1 Description of study areas

Study areas were located in the Alice Springs region of the Northern Territory of Australia. This region is part of the Australian Arid Zone (Figure 2.1) and is referred to as central Australia. Seventy four percent of Australia is considered arid (5,700,000 km^2), characterised by low average annual rainfall, associated with considerable variability, hot temperatures and high evaporation rates (Squires, 1981). The mean annual rainfall for Alice Springs is 274 ± 146 mm (SD) ranging from 46 to 1017 mm (1874-1988) and the annual mean evaporation rate is 3,600 mm based on Bureau of Meteorology (B. Met.) records. Rainfall is unpredictable with sequences of years below the mean (e.g. 1957 to 1965) or alternatively above the mean (e.g. 1972 to 1979) (Figure 1.3). Rain

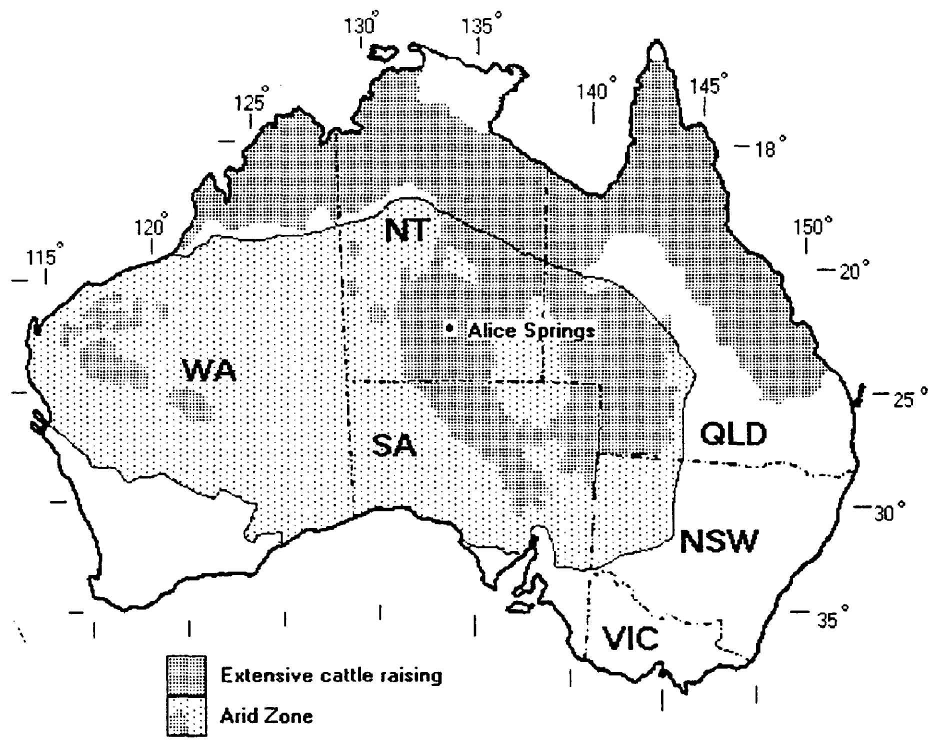


Figure 2.1: Map of Australia showing the Arid Zone and areas of extensive cattle raising. Compiled from Squires (1981) and Honour et al. (1969).

is more likely to fall in summer (Figure 2.2 and Table 2.1) as a result of the northern monsoonal influence; however, summers can be dry like 1984/85 and winters wet like 1986 (Figure 2.3).

During the period when I collected most of my data (1984-1986) day-time temperatures for October to January were often in excess of 39°C and some winter nights were below freezing, on one occasion as cold as -7°C. Winter days were usually warm (approaching 20°C). In central Australia temperature maintains a relatively stable and well defined seasonal pattern and has a lesser effect on plant growth than rainfall, although grasses are sensitive to cold conditions and remain virtually dormant

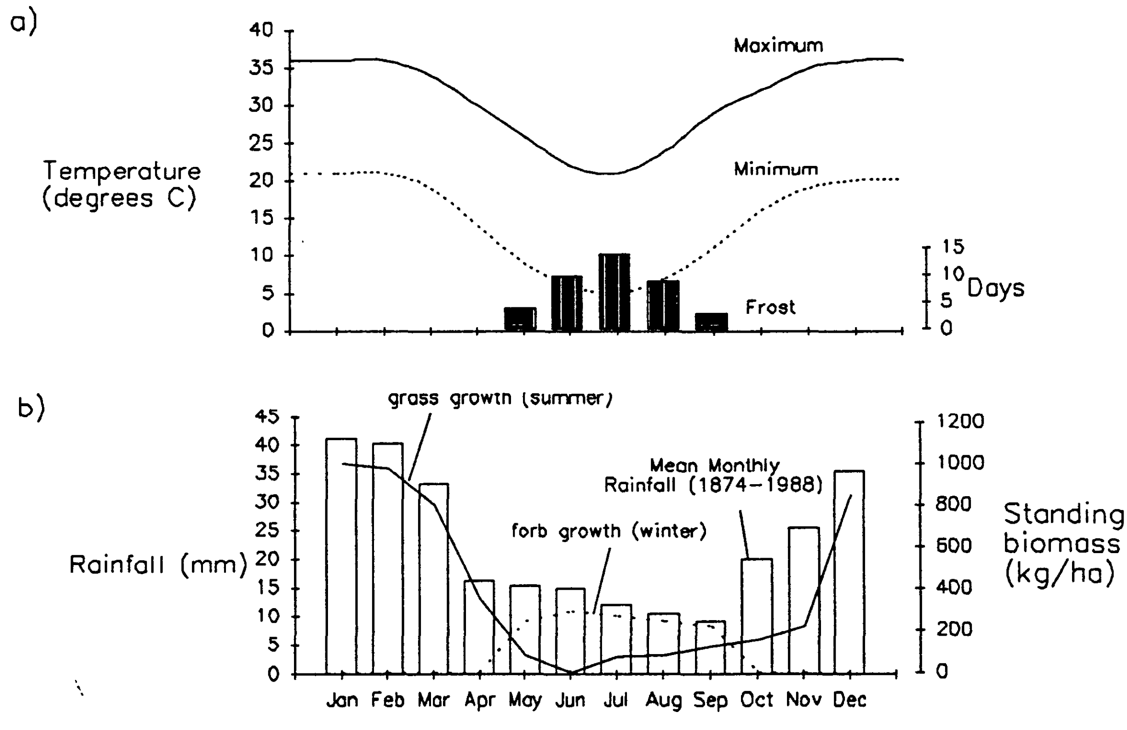


Figure 2.2: Mean temperature and days of frost shown in a), and rainfall (Alice Springs, B. Met.) and pasture growth assuming mean rain for all months shown in b) (adapted DPI&F Agnote; Foran et al. 1985).

Table 2.1: The descriptive statistics for rainfall recorded by the B. Met. at Alice Springs between 1874 and 1988. The standard deviation (SD) and coefficient of variation (CV %) are shown.

Season	Summer			Autumn		
Month	DEC	JAN	FEB	MAR	APR	MAY
Years	115	115	115	115	115	115
MEAN	36	41	40	33	16	16
SD	44	55	54	54	25	23
CV %	131	132	134	161	154	150
MEDIAN	20	15	17	12	5	3
MINIMUM	0	0	0	0	0	0
MAXIMUM	288	281	236	357	117	109

Season	Winter			Spring			ANNUAL
Month	JUN	JUL	AUG	SEP	OCT	NOV	
Years	115	115	115	115	115	115	115
MEAN	15	12	11	9	20	26	275
SD	21	17	15	12	24	30	302
CV %	139	198	213	174	105	101	53
MEDIAN	7	1	2	2	17	19	240
MINIMUM	0	0	0	0	0	0	46
MAXIMUM	101	144	158	90	116	139	1017

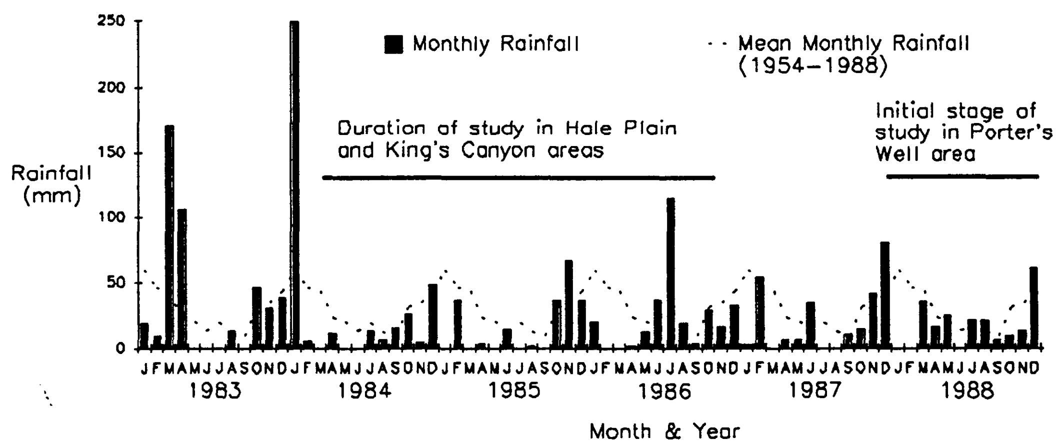


Figure 2.3: Long-term mean and actual monthly rainfall for The Garden station homestead (B. Met.) along with lines indicating the timing and duration of study in areas described in the text.

during winter even when significant rain falls (Figure 2.2). Figure 2.2 is an idealised representation of pasture growth if all months receive rainfall equal to the mean. This is unrealistic because rarely does rainfall equal the mean. Nevertheless, the figure illustrates the importance of summer rainfall and grass growth for pasture production. Rain tends to come in discrete "events" separated by dry periods of varying lengths. Figure 2.3 shows how good the rainfall was prior to the study; how dry it was during the study; and how variable the timing and amount of rainfall can be in central Australia.

For much of the time the rivers and watercourses are dry. The Todd River in Alice Springs flowed 25 times in eight years between 1981 and 1988 (Power and Water Authority). The sandy riverbeds were ideal camp sites because I could avoid the ants and prickles (burrs). It was highly unlikely that a flood would wash me away as I slept, although a film crew lost their camping equipment in a flood just last year. Fortunately they were not asleep but filming drought-affected horses down stream from their camp when their food and swags (bedding) floated passed. Rain had not fallen where they camped but had fallen in the river catchment 10 km away. This incident well illustrates the unpredictability of rainfall in central Australia.

Along the larger rivers where rock restricts subsurface flow ephemeral waterholes of varying size and persistance can be found. These provide water for horses, cattle and wildlife for at least a short time after rain. Even less common, but much more important for survival of animals during drought, are spring-fed waterholes that never dry up. Animals can also obtain water from artificial sources (bores and dams).

The rugged quartzite and sandstone ridges of the central ranges are surrounded by flat pastoral land merging into the Simpson Desert to the south-east and the Tanami Desert to the north-west (Figure 2.4). The deserts are generally well vegetated compared to other deserts of the world. The predominant vegetation is hummock grassland (spinifex steppe, *Triodia* spp.) containing scattered trees and/or shrubs growing on flat, sand plains or dune fields. Low woodland and shrubland dominated by *Acacia* spp. with a ground layer of ephemeral grasses and forbs occur over most of the pastoral land. There

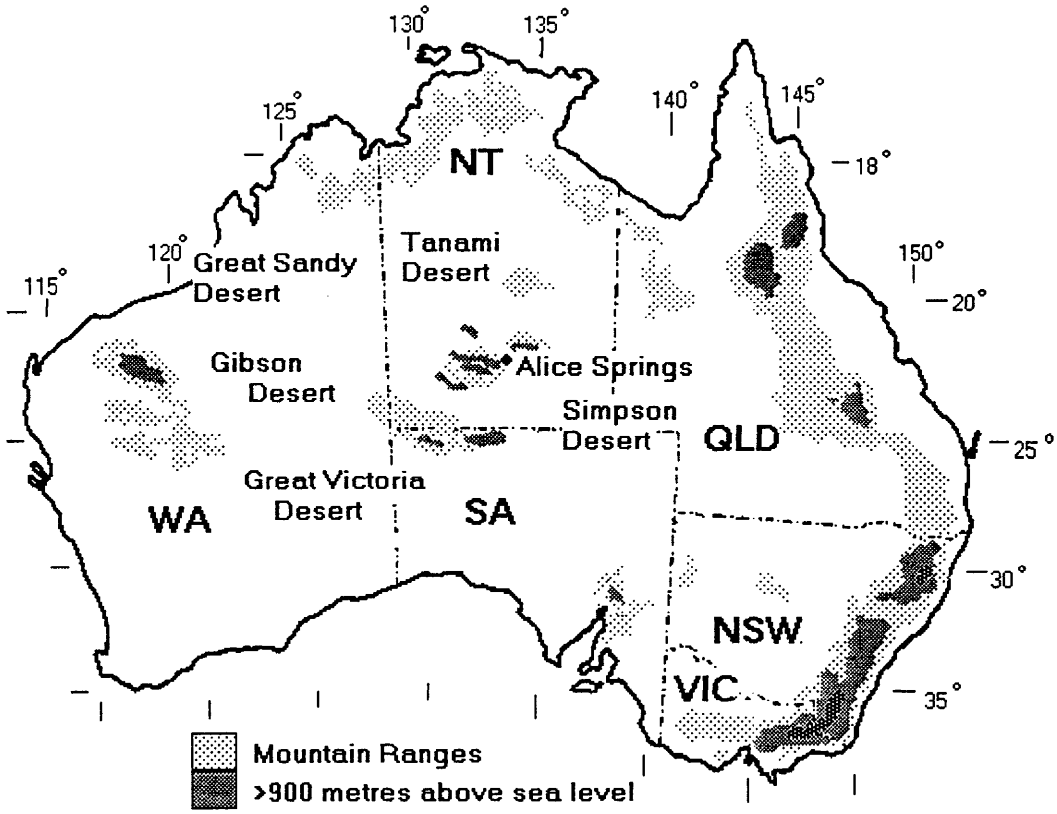


Figure 2.4: Map of Australia showing the distribution of mountain ranges and deserts. Compiled from Squires (1981) and Honour et al. (1969).

are also areas of bunch grassland consisting mainly of perennial grasses, particularly *Astrebla* spp.; and along the normally dry creeks and rivers there are woodlands dominated by river red gum trees (*Eucalyptus camaldulensis*) with a ground layer of perennial grasses.

Annual grasses such as *Enneapogon* spp. (oat and woollyoat grass) are preferred by cattle and are considered by range managers to be the most valuable pasture grasses of central Australia. *Enneapogon avenaceus* (oat grass) is widespread and one of the main species grazed by cattle (Leys, 1977; Squires, 1979). Perennial grasses are generally the least palatable particularly those of the *Aristida* genus. However, Mitchell grass (*Astrebla*) is a moderately palatable perennial and umbrella grass (*Digitaria coenicola*) is a highly palatable perennial that tends to disappear when heavily grazed by cattle (G. Bastin, pers. comm.). Spinifex grows in the driest and least fertile areas and is spiky and unpalatable. In general, summer rains encourage germination and growth of grass, whilst winter rains promote forb (non-grass herbaceous vegetation) growth (Figure 2.2). Apart from providing shade, trees and shrubs are supplementary fodder and drought reserve for cattle when grasses and forbs are dry, rank or low in nutritive value (Askew & Mitchell, 1978).

Central Australia is sparsely settled country, the main industries being tourism and extensive grazing of cattle (Figure 2.1). In the mountain ranges cattle are mustered once a year by helicopter or a combination of helicopter and horsemen. Motor bikes are not often used for mustering because the hills are too rocky and covered in scrub. Stock can be trapped in yards set up around watering points; however, the large number of alternative natural watering points restricts the use of trapping to times of drought. Musters are, therefore, often less than 100 percent successful and cattle, horses and donkeys have all established feral populations in the mountain ranges. Few properties have a complete boundary fence and internal fences are confined mainly to areas close to homesteads allowing feral stock free movement from property to property.

In terms of population ecology there is little difference between the management of feral horses and domestic cattle. Difficulties posed by the inaccessible, expansive country allow minimal manipulation of the distribution and abundance of both species. Cattle are mustered once a year for branding, castration and removal of those suitable for sale. Horses are generally mustered at the end of the year (beginning of summer) when the cattle work is finished and usually only if there are thought to be too many. Captured horses are generally sold for slaughter. Cattle may be removed from properties or paddocks when they become poor during drought and are brought back after good rainfall. Some horses are also removed to reduce density during drought but instead of being brought back by the manager they re-establish populations by immigration from surrounding areas or by breeding.

My principal study area was 70 km north-east of Alice Springs on The Garden cattle station (Homestead: 23°17' South, 134°25' East) (Figure 2.5). **The Garden Study Area** was conveniently close to Alice Springs, allowing continuous monitoring of horses, cattle

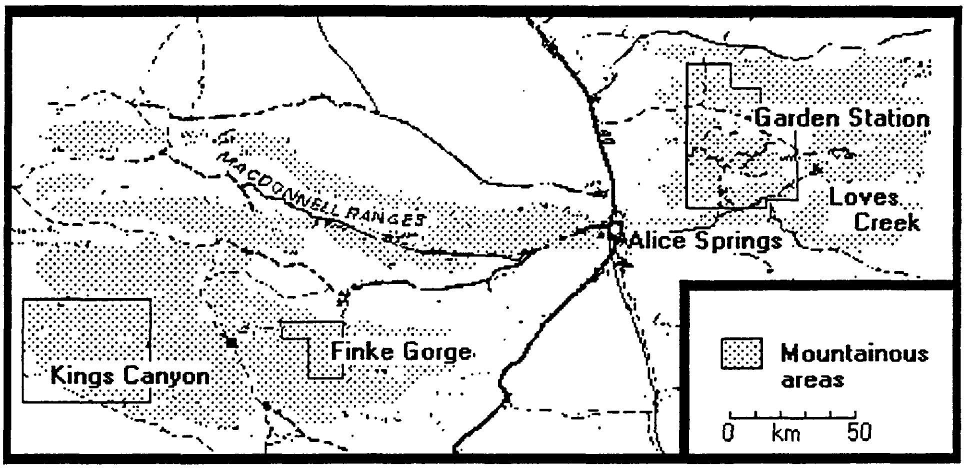
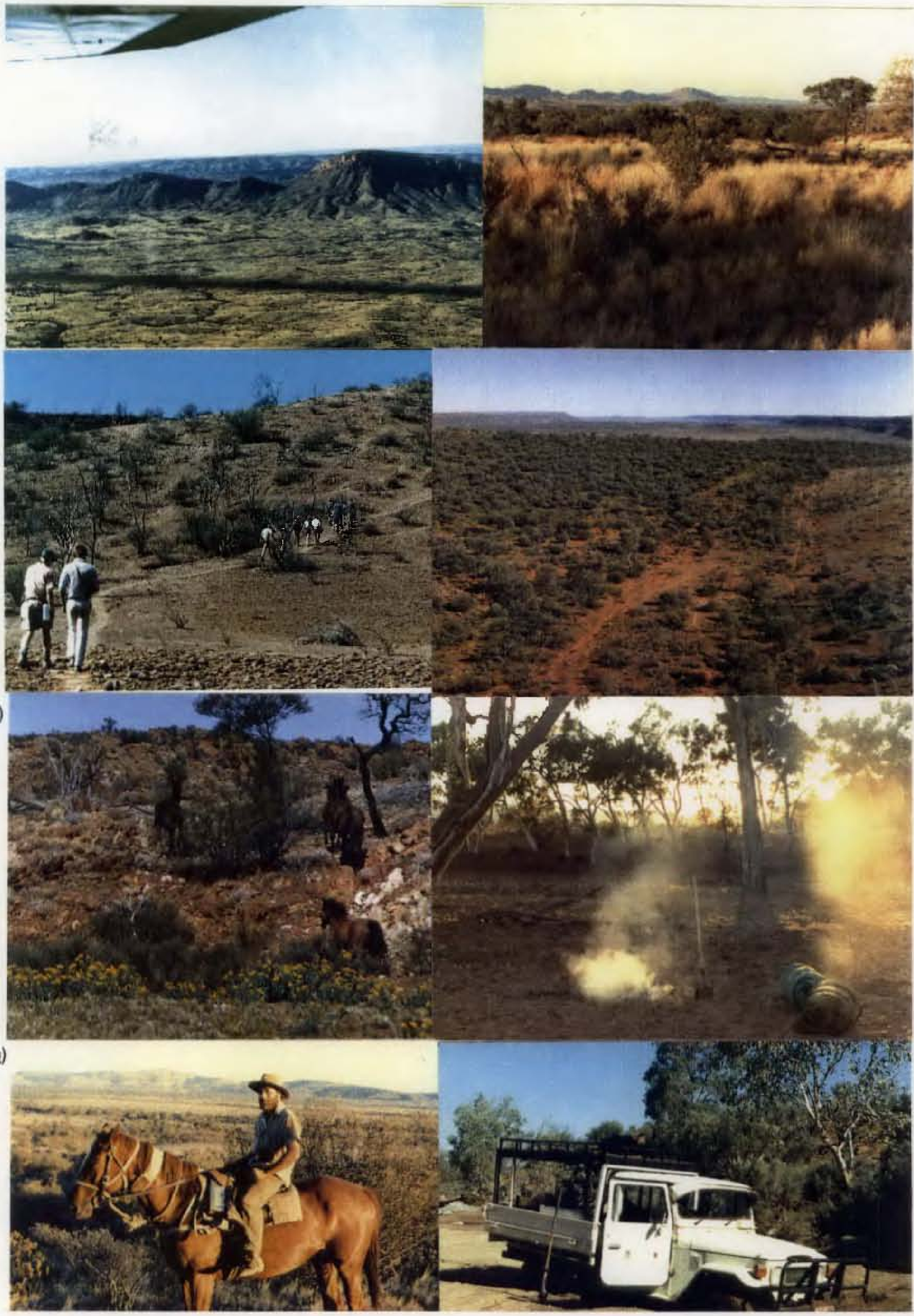


Figure 2.5: The Garden station and the area north of Kings Canyon were the main study areas. Data was also obtained from Loves Creek and Finke Gorge National Park. Feral horses inhabit most parts of the central mountain ranges.

and vegetation while I maintained contact with the CCNT and involvement with other projects of management of or research on feral horses. The activity, diet, habitat use, social organisation and population parameters were studied on The Garden station (Plate 1).

Horses and cattle occur sympatrically over nearly all their ranges in central Australia. To look at environmental impact of horses alone, I needed to find an area where they occurred without cattle, where I could assess their distribution and impact on the soil and vegetation. To do this I selected an area near Kings Canyon where there is a valley used by horses but not cattle. **The Kings Canyon Study Area** was located about 250 km south-west of Alice Springs just north of the George Gill Range on Tempe Downs cattle station (Tempe Downs Homestead: 24°23 South 132°25 East) and the adjacent Watarrka National Park (formerly known as Kings Canyon National Park) (Figure 2.5 & Plate 1). P.J. Jarman organised Operation Raleigh venturers, University of New England staff and students and Army personnel to work in the Kings Canyon area during a six week period in winter 1986 to study the environmental impact of feral horses. With all these helpers I was able to sample the distribution of animal signs, plant characteristics and soil erosion over a very large area (Chapter 8).



a) b) c) d) e) f) g) h)

Plate 1: Selection of study areas was based on inspection from the air (a) during the CCNT aerial survey and from the ground (b). The Garden station (a & b) was the major study area. A study of the environmental impact of feral horses was conducted in the Kings Canyon area (c & d) with the help of Operation Raleigh venturers, Army personnel and volunteer biologists (c). The Kings Canyon area was chosen because Dry Creek valley was used by horses but not cattle. Photo (c) shows Operation Raleigh expedition members climbing the "saddle" that restricts cattle but not horses from using Dry Creek valley. Dry Creek valley can be seen in the distance (d) and pads used by horses walking across the "saddle" 25 km from permanent water are visible. Most horses were very wary and usually fled into the rugged, rocky hills rather than be observed (e). I often camped in the dry river beds (f). "Rocky" my showjumper transported me and my computer along transects in the rugged hills to the south of the Hale Plain. Transect patrols were also conducted in the Toyota (h).

Information was also obtained during visits to other areas in central Australia (Figure 2.5). Post mortem examination of 195 horses for age, sex, condition and pregnancy rates were obtained at Loves Creek station. Condition, age, sex and group composition were recorded for horses seen at Finke Gorge National Park (Figure 2.5) and in the Davenport Ranges (300 km north of Alice Springs). I was also involved as an observer in aerial surveys of the Gulf and Alice Springs regions in 1984, The Garden station in 1986 and 1988, and the MacDonnell Ranges portion of the Alice Springs region again in 1988. All these surveys were conducted primarily to determine the distribution and abundance of feral horses.

From March 1984 to November 1986 field work was conducted in these mountainous areas of central Australia which are inhabited by large populations of feral horses. I then spent six months at the University of New England analysing data and writing a report with P.J. Jarman (Berman & Jarman, 1987) for the Conservation Commission of the Northern Territory before returning to central Australia to conduct further consultancy work. The work conducted during the second period of field work (March 1988 to April 1989) was reported in 1990 (Dobbie & Berman, 1990) and is used to support this thesis.

2.1.1 The Garden study area - for chapters 3 to 7 and 9

My first few months in central Australia were spent assessing potential study areas, negotiating with land holders and finally selecting The Garden station as the major study area. The Garden cattle station was chosen as the major study area because it had vegetation types, landform and natural watering points characteristic of areas where horses occurred in high densities at the time of the 1984 aerial survey (Graham et al., 1986; Bowman, 1985), and typical densities of horses were found there. Most pastoralists in the area are less than sympathetic towards Government Employees or Scientists from Universities. Fortunately the pastoralist Jim Turner was willing to allow work to be conducted on his property. The Garden station is approximately two hours drive from Alice Springs, closer than any of the other potential study areas. Like most central Australian properties there were few roads and data collection was often conducted off-road, either by vehicle or on horseback.

I sampled factors relating to horses, cattle and vegetation over the whole 2113 km^2 property from both the ground and air, although two areas within the property were defined for more intense sampling (Figure 2.6). On the **Hale Plain** study area (200 km^2) social group composition, condition, diet, habitat use and activity of feral horses were monitored in combination with measurement of changes in quality and quantity of pasture for 33 months (March 1984 to November 1986) (Figure 2.7). The **Porter's Well** study area incorporated the rugged south-western half (about 1000 km^2) of the property and was chosen in 1988 for studies using radio-tracking to determine movement patterns, home range characteristics and factors that may improve methods of mustering or control of feral horses.

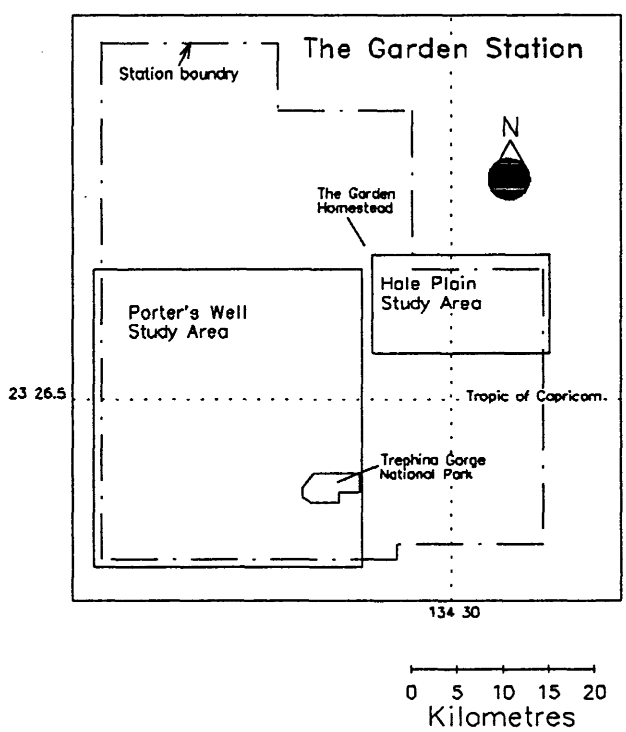


Figure 2.6: The Garden station study areas. Most intense sampling was conducted on the Hale Plain between 1984 and 1986. The Porter's Well area was used for a radio-tracking study between 1988 and 1990.

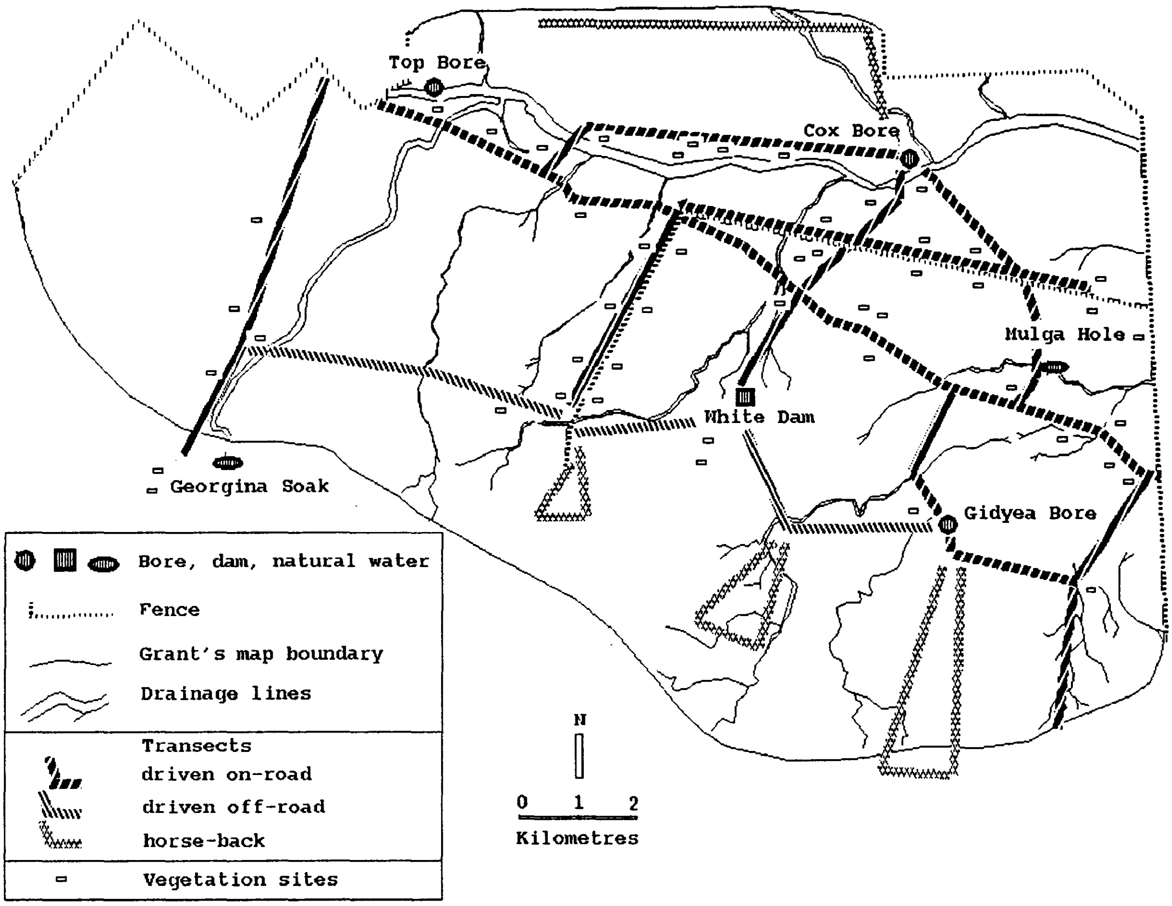


Figure 2.7: Map showing watering points, fences, transects and sites for vegetation assessment on the Hale Plain.

a) The Garden horses

The Garden is now a property primarily concerned with the production of cattle, but prior to the Second World War horses were bred there for sale to the British army in India. Although in the last 40 years few horses have escaped or been released into the feral population, the majority are still of a very high quality. Feral horses in other parts of the world generally, with time, tend to lose their good conformation, and become small with big heads and short necks. The horses of central Australia are, when judged on conformation, similar to domestic horses.

Heavy horses were originally bred to the west of The Garden homestead using mainly Clydesdale stock. These horses were bred for doing heavy jobs such as pulling artillery or dragging wild cattle up to a rail for branding (bronco branding). To the east of the homestead light horses were bred using mainly Thoroughbred blood. The heavy and light have interbred so that the wild population shows varying degrees of the Thoroughbred-Clydesdale combination. The average height at the withers of adult horses is 15.1 hands (approximately 150 cm), and they generally have solid bone, clean heads and feathered legs. Markings and colour were recorded for 150 horses; of these 49% were bay, 23% chestnut, 11% black, 11% brown and 5% grey. Forty three percent had a blaze or large white facial marking, perhaps a result of their Clydesdale ancestry.

Most of the feral horses of central Australia originated from horses bred for army remounts or stock work and are of similar type to those of The Garden station, although not all are of as high quality.

b) Water

Bores, dams, springs, soaks and water-holes are all used by stock (horses and cattle) for watering on The Garden station (Plate 2). Ephemeral water-holes contain water from between 2 days to 6 months depending on the size of the water-hole and the amount of rain. Soon after rain at least, these ephemeral water-holes allow stock to graze anywhere on the station without having to venture far from a place where they can drink. This situation does not last long, however, and stock often must walk 6 to 8 km from a water-point to feed. Twelve percent of available pasture on the Garden station is further than 8 km from permanent water (bores, springs or soaks) and 52% is further than 8 km from a permanent natural water-hole, spring or soak.

Plate 2: I used a variety of methods to collect data, often alone but occasionally people were employed or volunteered to help. I was an observer during CCNT aerial surveys (a). I conducted post mortem examination of horses shot in the field (b) or slaughtered in an abattoir or (c) found dead. In (d) my friend Steve Gann is shown sitting waiting to help me dart and radio-collar horses at a waterhole. I was occasionally able to delegate tedious jobs such as wheel-point assessment of vegetation (e) to people like Jill Smith. Jill also helped collect faeces for diet analysis (f) conducted by Kate Phillips at Armidale. Photo (g) shows an army truck full of Operation Raleigh venturers, soldiers and biologists who helped in the study of environmental impact. Often Dr Jekyll was the only assistant willing to listen to my instructions (h).

c) Vegetation

The sandy river beds are lined by shady river red gum trees (*Eucalyptus camaldulensis*) and dense perennial grasses (*Enteropogon ramosa, Bothriochloa ewartiana* and *Eulalia fulva*). Ironwood (*Acacia estrophiolata*) and corkwood trees (*Hakea* spp.) dominate the alluvial plains adjacent to drainage lines and provide some shade for stock. These alluvial plains grow perennial grasses (*Aristida browniana*), cottonbush (*Maireana aphylla*), saltbush (*Atriplex* spp.) and, after winter rainfall, herbaceous forbs (various daisies and the poisonous species, *Swainsona* and *Indigofera*). There are treeless gilgaied plains dominated by perennial grasses, Mitchell (*Astrebla* spp.) and neverfail (*Eragrostis* spp.) and further up the catena on colluvial terraces both annual and perennial grasses are found. Mulga trees (*Acacia aneura*) provide some shade on the rolling to steep hills where annual grasses predominate. The rugged mountain ridges have low bush over spinifex (*Triodia* spp.).

d) Habitat

Perry et al. (1962) mapped (regional mapping scale of 1:1,000,000) and described 88 distinctive land systems in a report on the lands of the Alice Springs area (400,000 km^2). Of these 88 land systems only 6 (Bond Springs, Sonder, Harts, Huckita, Gillen and Ambalindum) occur on The Garden station (Perry et al., 1962) (see Figure 2.8 & Table 2.2). Land systems are a composite of related units, throughout which there is a recurring pattern of topography, soils and vegetation (Christian & Stewart, 1953 cited by Grant, 1986). Units of similar topography, soils and vegetation may appear in different land systems. Although the Hale Plain study area has only 3 land systems (Perry et al., 1962), the country can be classified into a number of smaller units which have topography, soil and vegetation similar to land units of different land systems elsewhere.

2.1.2 The Hale Plain - for chapters 3 to 7

According to Perry the Hale Plain study area (200 km^2) is predominantly Ambalindum land system (71%), bordered on either side by Harts (27%) and in the south by Sonder (2%) (Figure 2.8 & Table 2.2). Perry's land systems were not considered

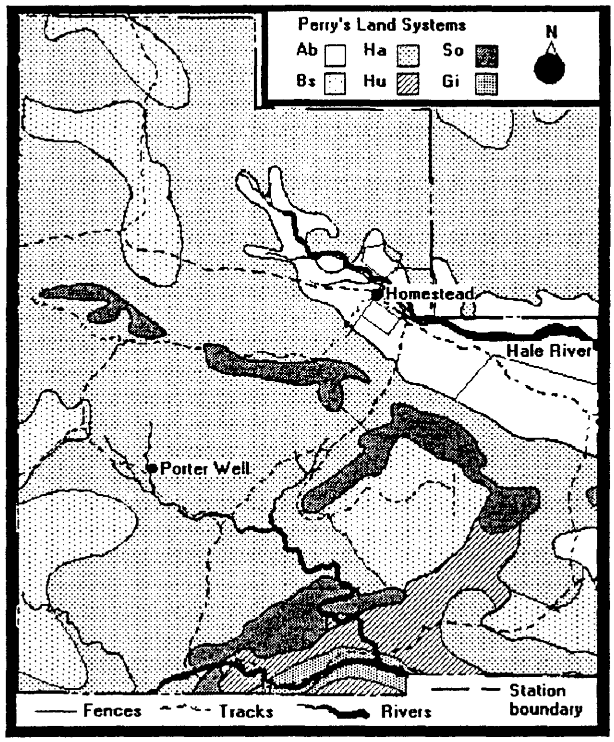


Figure 2.8: Perry's Land Systems of the Garden Station. See Table 2.2 for description of each Land Systems.

sufficiently detailed for the purposes of intensive studies on the Hale Plain.

a) Grant's land units of the Hale Plain

To examine seasonal changes in habitat use by horses and the degree of habitat overlap between horses and cattle on the Hale Plain (200 km^2), a detailed land unit classification was required. A land resource survey was conducted during March 1985 by the Soil and Land Resources Unit, Conservation Commission of the Northern Territory, Alice Springs (Grant, 1986). Grant produced a very detailed land unit map with homogeneous land units from colour aerial photographs (1:20,000). Landform, soil and vegetation attributes were recorded at 50 sites, and vegetation alone at a further 50 locations. Classification of the 28 units was based on geology, soil, vegetation and landform.

Grant's land units proved to be sufficiently detailed for the purposes of this study and allowed grouping into less detailed units to fit the intensity of sampling possible. The intensity of sampling was therefore limited only by the available sampling time not the accuracy of land unit classification. Units were grouped based on similarity of dominant pasture species and topography or relief (see Table 2.3 and Grant, 1986).

Table 2.2: Perry's Land Systems on The Garden station and the Hale Plain study area. The Hale Plain area includes only the area mapped by Grant (1986).

Perry's Land Systems	HA	BS	AB	SO	HU	GI	TOTAL
Garden Station							
area (%)	58%	20%	11%	5%	5%	1%	
(km^2)	1219	420	228	114	108	24	2113
Hale Plain							
area (%)	27%	-	71%	29%	-	-	
(km^2)	54	-	142	4	-	-	200

Description of Perry's Land Systems		
HA	Harts	Uplands,steep-sided mountains, and, hills, relief about 300 m; pockets of shallow gritty and stony soils; sparse shrubs and grasses
BS	Bond Springs	Ridges up to 100 m high and rugged terrain up to 30 m relief; some shallow gritty and stony soils; sparse shrubs and grasses. Narrow plains; various soils; sparse low trees over short grass.
AB	Ambalindum	Weathered high terrace remnants, dissected low calcareous terraces, and derived alluvial plains, relief up to 50 m; stony texture-contrast soils, some red clay soils; open, *Sclerolaena* spp. or *Astrebla* spp.
SO	Sonder	Bold quartzite and sandstone ridges with rocky cliffs and steep slopes, relief up to 700 m; very little soil; spinifex
HU	Huckitta	Mountain ranges with rounded foothills and spurs, relief up to 200 m; little soil; spinifex or sparse grass
GI	Gillen	Quartzite and sandstone ridges up to 300 m high; little soil; spinifex

Table 2.3: Vegetation, soil and landform units derived by grouping Grant's land units (Grant, 1986). See Table 2.2 for a description of Perry's Land Systems.

PERRY'S	GRANT'S	Unit	DESCRIPTION
SO	1.1	A	Rugged mountain ridges; pockets of lithosols with scattered low bush over spinifex.
HA	1.2 1.3 1.4	B	Steep hills, low rolling hills and gently undulating low hills; mainly annual grass (*Enneapogon* spp.).
AB	2.1-2.2 3.5-3.6 4.1-4.2 5.1 5.3-5.4	C	Pediment-plains and tributary drainage floors; sandstone terrace valley floors and drainage floors; limestone terraces; colluvial terraces; mainly annual grass (*Enneapogon* spp.).
AB	2.3 5.5-5.6 6.1-6.5	D	Swampy areas; Drainage floors-cotton-bush; Alluvial surfaces; very little annual grass; mainly perennial grass (*Aristida browniana*, *Enteropogon* spp.) saltbush or cottonbush.
AB	3.1-3.4	E	Sandstone terraces; mainly perennial grass (*Aristida* spp.) with some annual grasses (*Enneapogon* spp.).
AB	4.3-4.4	F	Limestone gilgaied plains and drainage floors; very little annual grass; mainly Mitchell (*Astrebla* spp.) and neverfail (*Eragrostis* spp.) grasses.
AB	5.2	G	Colluvial terrace gilgaied plains with Mitchell grass (*Astrebla* spp.) and annual grasses (e.g. *Enneapogon* spp.).

Areas dominated by annual grasses were separated from those dominated by perennial grasses because of the expected difference in preference by stock. Pasture species have varying palatabilities (Department of Primary Production Range Herbarium, 1982; see Chapter 4). The distribution of stock was influenced by topography in north America (Cook, 1966; Miller, 1983) perhaps either because climbing hills requires more energy than walking on flat land or because of topography-related changes in vegetation.

b) Description of the Hale Plain habitat

The Hale plain study area is bordered to the south by a rugged quartzite ridge called the Georgina Range (unit A) (Figure 2.8, Table 2.2 & Plate 3). The top of the range is 1034 m above sea level and 400 m above the Hale River 9 km to the north. The last one kilometre to the top on the northern side ascends 200 m. On the southern side there is a virtual cliff dropping 200 m in 150 m. Apart from two gaps (Georgina Gap is fenced and the other gap is small and secluded) the Georgina Range is a barrier to stock. The steep to gently undulating foot-hills of the Georgina Range (unit B) have lithosols based on metamorphic rocks. Similar hills (unit B) border the northern edge of the Hale Plain. The hills of unit B grow annual grasses, mainly *Enneapogon* spp. (woollyoat and oat grass), are flatter than the quartzite ridges (unit A) but generally steeper than the terraces (unit C and G). Gently sloping plains and flat areas dominated by annual grasses, mainly *Enneapogon* spp. (oat and woollyoat grass), were grouped to form unit C. Other terrace surfaces with *Aristida* spp. and sparse or absent *Enneapogon* spp. made up unit E. Gilgaied terraces (unit G) with *Astrebla* spp. (Mitchell grass) and *Enneapogon* spp. (woollyoat grass) were left separate from other gilgaied areas which generally had a lower relief and did not grow annual grasses (unit F). The alluvial plains (unit D) have the lowest relief and grow mainly perennial grasses (*Aristida browniana, Enteropogon ramosus*), cottonbush or saltbush, or were denuded at the time of the study. Table 2.4 and Figure 2.9 show the area of each land unit on the Hale Plain.

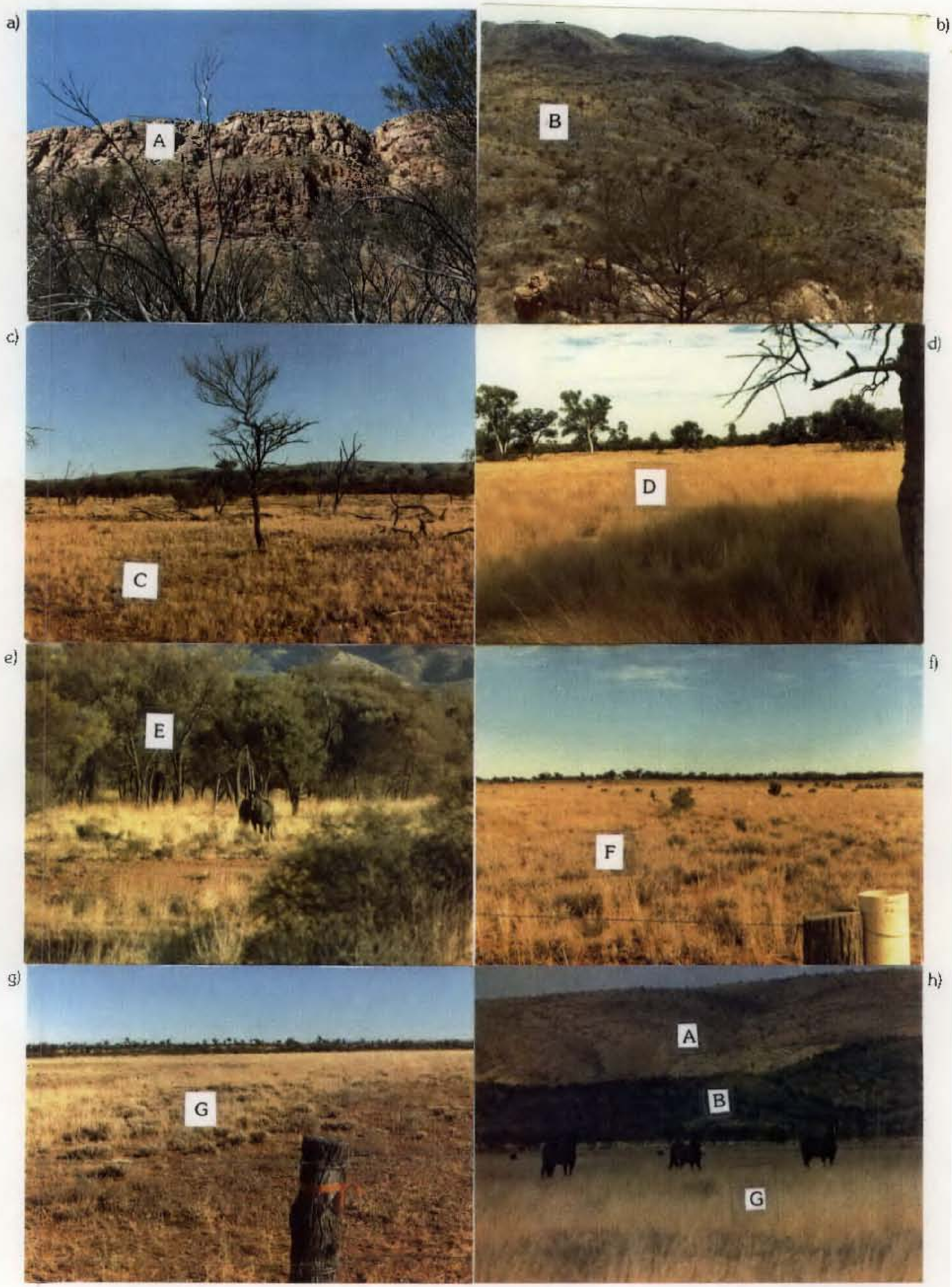


Plate 3: Land units of the Hale Plain (see Table 2.3 for description).

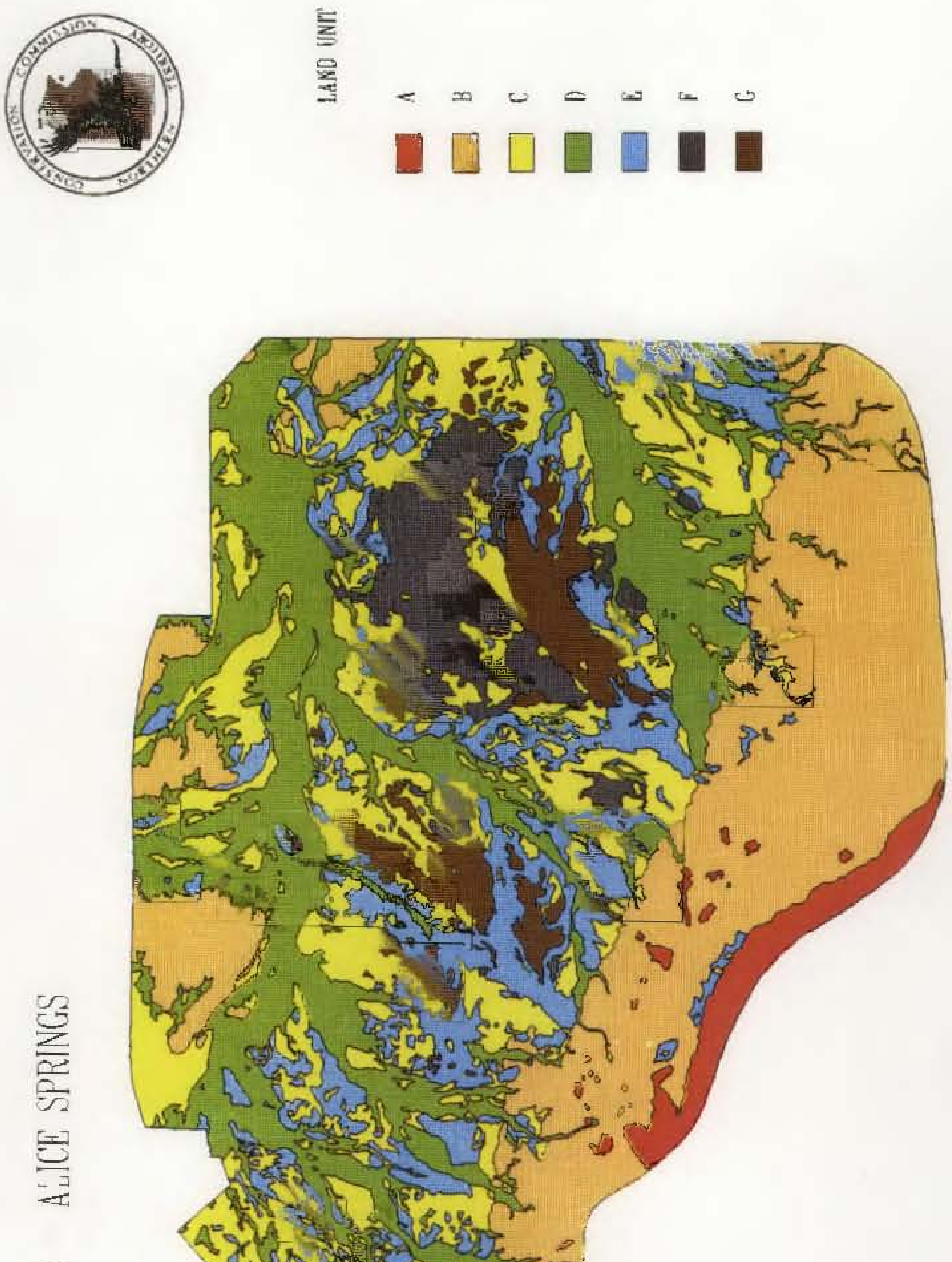


Figure 2.9: The Hale Plain study area mapped into vegetation, soil and landform units by Grant (1986). See Table 2.3 for description of units and Figure 2.7 for location of transects, sites, water and fences.

Table 2.4: Area of units (percent and square kilometres) on the Hale Plain determined from Grant's land unit map.

Unit	Percent	AREA(km^2)
A	2%	4
B	27%	54
C	16%	31
D	29%	57
E	18%	36
F	6%	11
G	3%	6

c) Land unit and distance from watering point

On the Hale Plain the stock were able to drink permanently at three bores and a soak, and periodically at a dam and numerous ephemeral water-holes. Land units were divided further using 4 categories of distance from water (1: 0-0.5 km, 2: 0.6-3 km, 3: 3.1-6 km and 4: >6 km) creating 28 units (Table 2.5). Areas close to water were expected to have different use by horses and cattle to those areas more distant (for cattle Hodder & Low, 1978; for cattle and horses Miller, 1983). Figure 2.7 shows the location of the watering points on the Hale Plain and Table 2.6 shows the area of each land unit greater than 0.5 km and less than 3 km from these watering points.

Table 2.5: Area around each watering point for the distance categories (1: 0-0.5 km, 2: 0.6-3 km, 3: 3.1-6 km and 4: >6 km) when water is available for stock at White Dam.

Category	Area (km^2)					
	Top Bore	Cox Bore	Gidyea Bore	White Dam	Georgina Soak	Hale Plain Total
1	1	1	1	1	1	4
2	17	24	28	26	9	99
3	40	17	37	21	31	94
4	4	0	0	0	4	4
Overlap						
2 Gidyea	-	-	-	5	-	
3 Gidyea	-	-	-	20	-	
3 Top	-	13	-	-	20	
4 Top	-	-	-	-	4	

2.1.3 Porter's Well area - for chapters 3 to 4 and 6

The Porter's Well area is more rugged, has a larger number of watering points, fewer fences and less human activity than the Hale Plain. Consequently horses are more nervous and difficult to observe; they retreat quickly into the hills and mulga trees when disturbed by vehicles or horsemen.

a) Habitat

The Porter's Well area is predominantly Harts land system, uplands, steep-sided mountains, and hills, relief about 300 m with pockets of shallow gritty and stony soils and sparse shrubs and grasses. Bond Springs land system (ridges and rugged terrain) occurs

Table 2.6: Shows the area of land units (mean percent) greater than 0.5 and less than 3 km from watering points on the Hale Plain (rounding errors mean totals are not necessarily exactly 100%).

Unit	Watering points on the Hale Plain									
	Top Bore		Cox Bore		Gidyea Bore		White Dam		Georgina Soak	
	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2
A	0	0	0	0	0	0	0	0	10	1
B	17	3	1	0	16	4	8	2	51	5
C	21	4	11	3	23	6	28	7	5	0
D	42	7	65	16	51	14	5	1	9	1
E	21	4	19	5	5	1	31	8	25	2
F	0	0	4	1	1	0	19	5	0	0
G	0	0	0	0	5	1	10	3	0	0

to the west and south-west while the quartzite ridges of Sonder land system with its rocky cliffs border the north, east and southern parts of the area.

b) Water

Stock can obtain water for one to two months after rainfall at countless rockholes, springs and soaks in the Porter's Well area. There are 5 bores and 4 dams. At least 18 important natural watering points hold water for periods longer than 9 months even when no rain falls. Four or five natural watering points are considered permanent and have never been known to dry up.

2.1.4 Kings Canyon study area - for chapter 8

Work conducted in the Kings Canyon area aimed primarily to determine if horses were having a measurable impact on the environment, and to distinguish between the impacts of horses and cattle. As mentioned previously horses and cattle occur sympatrically over nearly all their range in central Australia. To distinguish between the impacts of horses and cattle I needed to find an area where horses occurred without cattle. The Dry Creek valley (Plate 1 & Figure 2.10) was the only area in central Australia where I could find horses but not cattle. The reason for this was the lack of water and the fact that stock have to climb a steep ridge (the saddle) (Plate 1 & Figure 2.10) to enter the valley. Horses but not cattle were doing this.

Studies in the area also provided an opportunity to gain insight into relationships between feral horses, native wildlife, cattle, camels, rabbits and vegetation in areas up to 60 km from permanent water. This could not be done on The Garden station because there were few areas (15% of the station) more than 8 km from permanent water.

In June and July 1986, after almost 28 months with no significant rainfall, two neighbouring valley systems (including the Dry Creek) were surveyed by transects to count animal signs, and to assess soil erosion and vegetation. I was able to sample the vast areas required through the assistance of Operation Raleigh venturers, Army personnel and University of New England staff and students (Plate 1). The valley systems are situated approximately 250 km south-west of Alice Springs just north of the George Gill Range (Figure 2.10). The valley systems are long (60 km) and narrow (3-5 km) with steep rocky sides which restrict stock movement out of the valleys (Plate 1 & 8). Nineteen Mile valley (used by both horses and cattle) was surveyed over 60 km in a cline away from a single permanent watering point (but with a few temporary watering points) (Figure 2.10). The second valley system in fact involved two valleys (Petermann where the permanent spring was located and Dry Creek) separated by a ridge (saddle) which is a barrier to cattle but not horses (Plate 1). Here we studied country (Dry Creek valley) used by horses but not cattle, 30 to 55 km from permanent water (Farrer Spring) at which the horses were required to drink. Bagot Spring is only 10 km from the Dry Creek Valley (Figure 2.10); however, there was no sign of stock moving between Petermann Pound and Bagot Spring, although it is possible for them to do so. The steep rocky ridge between the valley systems (Nineteen Mile and Dry Creek/Petermann) appears to be a barrier to stock and therefore the two valley systems were assumed to contain independent populations of horses and cattle.

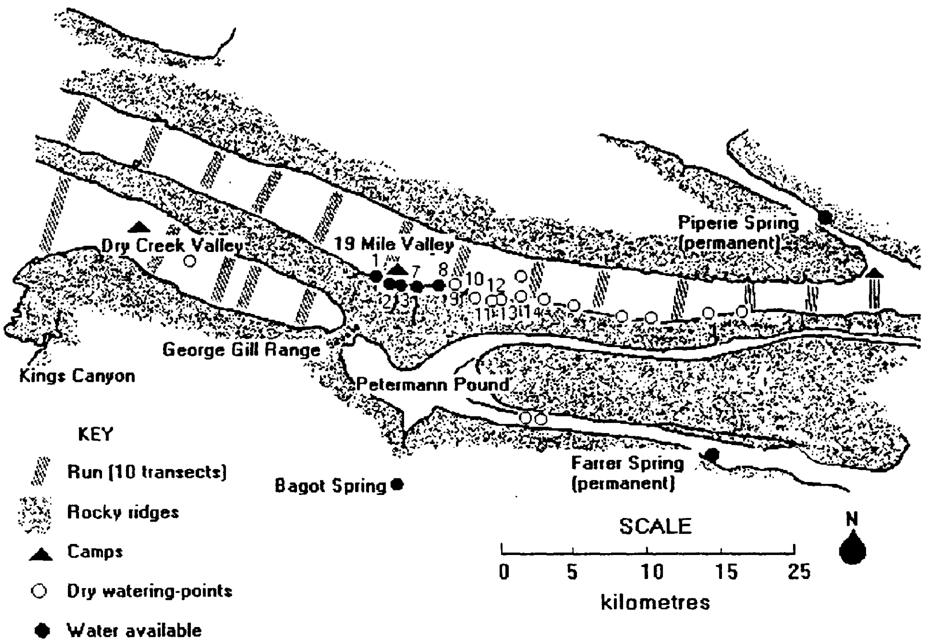


Figure 2.10: Kings Canyon study area where the Operation Raleigh Expedition studied the environmental impact of feral horses. Dry Creek valley is one of the few areas in central Australia with horses but no cattle.

a) Selection of study area and methods

Excluding horses from fenced areas was considered as a method to study the impact of feral horses but rejected because exclosures are expensive to construct and maintain. Also, such experiments often require monitoring for periods in the vicinity of 30 years before useful results are obtained (Foran et al., 1982). Barney Foran of the CSIRO (Commonwealth Scientific and Industrial Research Organisation) was already conducting exclosure experiments in areas grazed by cattle and rabbits and advised against their use for our study.

Selection of the study area was based on ground and aerial surveys conducted in 1984 and 1985. These surveys identified Dry Creek valley as an area used by horses but not cattle. Dry Creek valley appeared to be a suitable place to identify differences between the environmental impact of horses and cattle. The horses feeding in Dry Creek valley were presumably drinking intermittently at Farrer Spring in the Petermann valley to the east (Figure 2.10). Horses are more mobile than cattle and can travel further from a watering point and over rougher terrain in search of food (Berman & Jarman, 1987). In Nineteen Mile valley horses and cattle watered at the permanent spring to the east and semi-permanent water-holes along the southern valley wall. Nineteen Mile valley, used by both horses and cattle was selected as a comparison to Dry Creek, and because it represented an uninterrupted (by hills) 60 km cline from permanent water (Piperie Spring).

In June 1985 30 sites were marked out with star pickets at 1 km intervals along the Dry Creek valley with the help of CCNT ranger Alan Anderson. These sites were assessed for pasture biomass, amount of horse and cattle dung and the quality (green/dry, leaf/stem ratios) of pasture (methods explained in detail in Section 2.2.2). Fixed point photographs were taken with a view to repeated assessment. The results of this work showed a decrease in the intensity of horse use and an increase in pasture biomass with distance from the eastern end of the valley where horses entered from Petermann Pound. Although the results were promising the usefulness of this study was limited by the small number of sites. Grazing-induced changes may have been concealed by the great variation in vegetation, soil and landform. Increasing the number of sites was not possible due to the limited time available given that this study was only a small part of the feral horse work being conducted by the University of New England at that time. To increase the number of sites sampled and to sample intensively Nineteen Mile valley as well as Dry Creek valley, Peter Jarman applied for and received help from Operation Raleigh. Operation Raleigh is a scheme that organises young people from all over the world to help with scientific projects. Logistic support in the form of transport and camping equipment was supplied by the Australian Army. Army personnel also helped with data collection. Peter Jarman also arranged for staff and students from the University of New England to supervise the data collection. I devised sampling techniques suitable for people with no training in biology and coordinated the whole operation.

b) History of the valleys

A former owner of Tempe Downs station (1930 to 1938), Brian Bowman, was interviewed in June 1988 to obtain an idea of how the study area might have changed during its pastoral history. Bowman said there are far more shrubs in Nineteen Mile valley now than there were 60 years ago, a result he ascribed to increased rainfall but he had not noticed changes in the amount of soil erosion.

There have been large numbers of feral horses in the area for many years and in Bowman's day horses were caught and sold "for a good price". According to Bowman the demand for horses was strong during the depression because people were forced to sell their cars and buy horses for transport. He trapped 600 horses at Farrer Spring in the Petermann valley at the end of 1933. Those that could be roped and hobbled were taken and sold or used for stock work. The rest were shot. During dry times Bowman said that many horses died of starvation in the area around water-holes.

At present horses but not cattle use Dry Creek valley. They enter from the east to graze then return to the Petermann valley to drink at Farrer Spring. However, in the past both cattle and horses were run in Dry Creek valley by Bowman and a previous owner. They watered in King's Creek at the eastern end of Dry Creek valley near Kings Canyon.

Bowman said that there were three main semi-permanent rock-holes in Nineteen Mile valley but none of them hold water longer than 11 months. He also told of a water-hole at the western end of Nineteen Mile valley that held water for up to 4 months after rain. This western water-hole was not found during the present study but if it still exists may explain the unexpected (because of distance from known water) presence of old cattle dung and stock pads in the area.

It became apparent from talks with Bowman that few if any parts of the valley systems have escaped the past influence of both horses and cattle. However, Dry Creek was still the closest I could find to an area currently free of cattle but used by horses.

c) Geology

The geology of the area (Lake Amadeus) was mapped at a scale of 1:250,000 by Wells et al. (1962) for the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Dry Creek/Petermann valley system is bordered by high prominent escarpments (Mereenie Sandstone) overlying steep, scree-covered slopes (Carmichael Sandstone). Alluvium-covered strike valleys (Stokes Siltstone) and strike ridges (Stairway Sandstone) make up the Dry Creek/Petermann valley floor. Nineteen Mile valley is a wide alluvium-covered valley with some Parke Siltstone and Travertine, bordered to the south and north by high prominent escarpments of Mereenie Sandstone and Hermansburg Sandstone respectively.

d) Mapping land units

The areas crossed by transects (Figure 2.10) in Nineteen Mile valley were mapped into land units by Russell Grant (Land Resource Section, CCNT) through the stereo-interpretation of landform pattern on 1:50,000 scale colour aerial photography, with reconnaissance "ground truthing" by helicopter traverse. Within the limitations of the mapping scale and restricted site inspection, each unit has uniform geomorphic, soil and vegetative characteristics. Description of mapped land units appear in Table 2.7. The time available did not permit mapping of both valley systems.

e) Erodibility (erosion hazard)

Each unit was given a soil erodibility (erosion hazard) rating (0-3) based on its soil characteristics and principal mode of geomorphic activity. For instance, drainage floors with deep alluvial soils were given a moderate gully erosion hazard (Table 2.7) but no scalding risk. On the other hand, erosional slopes with duplex soil profiles (possibly associated with siltstone substrate) were considered to have a high scalding hazard and a moderate potential for shallow gullying. Sandplain and dunefield soils, with deep sandy soils that generate little runoff, were assessed to have no erosion hazard.

Table 2.7: Describes land units for areas crossed by transects in Nineteen Mile valley. Each unit was given a soil erodibility (erosion hazard) rating (0-3).

LAND UNIT DESCRIPTION	VEGETATION	ERODIBILITY		%
		Gully	Scald	AREA
1. Footslope fans flanking valley sides.	spinifex (Triodia spp.)	0	0	9
2. Alluvial sandplain on valley floor.	witchetty bush (Acacia kempeana), woollybutt (Eragrostis spp.)	1	0	16
3. Dunefield or single dune.	blue mallee (Eucalyptus gamophylla), spinifex	0	0	5
4. Valley floor pediment (bedrock plain).	Cassia spp., annual grasses	0	1	7
5. Drainage floor.	mulga/witchetty (Acacia spp.), 8-day grass (Fimbristylis dichotoma)	2	0	1
6. Drainage floor with duplex soils.	dead finish (Acacia tetragonophylla), curly windmill grass (Enteropogon spp.), desert bluegrass (Bothriochloa ewartiana)	2	3	4
7. Scalded footslopes.	southern bluebush (Maireana astrotricha)	2	3	8
8. Terrace footslopes or residuals.	oat grass (Enneapogon avenaceus)	0	2	2
9. Sandy alluvial fan.	ironwood (Acacia estrophiolata), mulga corkwood (Hakea spp.), woollybutt	1	0	35
10. Terrace surface/valley fill red earths.	oat grass	0	0	5
11. Drainage floor; medium textured red earth.	desert bluegrass, curly windmill grass	2	0	5
12. Alluvial/duplex soils.	ironwood, mulga 8-day grass, annual grasses	3	2	5

f) Vegetation

Both valleys had similar plant species. Dominant trees were mulga (*Acacia aneura*) and ironwood (*Acacia estrophiolata*) with river red gum (*Eucalyptus camaldulensis*) growing along the major water-courses. Witchetty bush (*Acacia kempeana*) and *Cassia* spp. were common. The perennial grass woollybutt (*Eragrostis eriopoda*) was the only grass visible in many parts of Nineteen Mile valley during the Operation Raleigh expedition (June 1986). Curly windmill grass (*Enteropogon ramosus*) and desert bluegrass (*Bothriochloa ewartiana*) grew along the major water courses. The palatable annuals, oat and woollyoat grass (*Enneapogon* spp.) and the palatable perennial, umbrella grass (*Digitaria coenicola*) were seen in the far west of both valleys. These palatable species were found right along Dry Creek valley in June 1985 and probably are normally more wide-spread in Nineteen Mile valley than was observed in June 1986. Grazing may have removed them from much of the valley.

2.2 Data collection on The Garden - for chapters 3 to 7 and 9

The Garden Study Area was chosen as the best place to determine the degree of dietary and habitat overlap between horses and cattle. From this I aimed to make inferences about competition between these two introduced ungulates. To interpret changes in diet and habitat use it was necessary to monitor changes in vegetation quality and quantity. So as well as collecting faecal samples and patrolling ground-based transects on The Garden station I assessed vegetation. Whilst patrolling transects I record data to determine patterns of daily and seasonal activity, changes in body condition, reproductive rates and social group composition for feral horses and cattle. I attempted to combine as many of these data gathering activities as possible. For instance sites were selected for vegetation assessment along transects that were regularly patrolled to record information about horses and cattle (Figure 2.7). Vegetation assessment was therefore incorporated into running of animal transects. I had no information to indicate the intensity required for adequate sampling of animals or plants so I sampled as intensively as time permitted. The use of the Sharp Pocket Computer allowed me to handle such large amounts of diverse data simultaneously. The strategy for data collection was modified and fine tuned as the study progressed so that the maximum amount of information could be collected in the most efficient manner.

Factors relating to horses, cattle and vegetation were sampled over the whole 2113 km^2 property, although more intense sampling occurred on a 200 km^2 section along the Hale River. I conducted ground-based transects and measured changes in quality and quantity of pasture during 33 months (March 1984 to November 1986) on the Hale Plain. Data were also collected on movement and activity patterns of radio-marked horses and cattle on the Hale Plain between July 1985 and August 1986.

The rugged south-western half (about 1000 km^2) of the property (Porter's Well Study Area) was chosen in 1988 for further studies using radio-tracking to determine movement patterns, home-range characteristics and factors that may improve methods of mustering or control of feral horses (Dobbie & Berman, 1990).

2.2.1 Diets of horses and cattle - for chapter 4

Cattle and horses are now the most numerous large herbivores in central Australia. To understand the potential for ecological competition between them, I needed to know what each species ate, preferably from the same pastures. To discover this I collected faecal material and sent it back to the University of New England where P.J. Jarman developed appropriate methods and C.M. Phillips performed microscopic analysis.

a) Field collection of faeces

Faecal material was collected from a number of sites on The Garden early in the study, and used to test and develop methods. From July 1984 to September 1986 faeces were collected at roughly two-monthly intervals. At first faeces were taken where either cattle or feral horses were currently most active. However, preliminary analyses showed that faeces collected at a bore did not differ from those collected elsewhere in the same paddock. Figure 2.7 shows how the Hale Plain is divided into two paddocks by fence and hills. Recently deposited faeces were much easier to find at bores or dams, so in the second year of the study faeces were collected mainly from the vicinity of bores or dams. An effort was made to get a fresh sample from both horses and cattle from each of the major bores in each sampling period. By this technique we hoped to get a sample that would represent diets of stock in the paddock supplied by that bore. There was no direct way of telling where any individual animals (cattle or horses) had been feeding, but the results of transect patrols were used to say which vegetation types were favoured by each species at the time of sampling.

When collecting samples in the field, I sought fresh faeces so that they would represent the current diets of the animals. Fresh faeces were also more likely to represent several different individual cattle or horses, rather than to be an accumulation formed by one animal repeatedly visiting the bore over a long period of time.

Faecal samples were either placed in labelled paper bags in the field and air-dried, later to be oven-dried and stored dry or frozen until analysis, or (more usually and, latterly, exclusively) were collected and stored directly in formal-acetic-alcohol (FAA). The samples were sent to the University of New England for analysis. The analyst did not know the sites from which the samples were taken nor, except by simple recognition, the species of animal they represented. This 'blind' procedure for the analysis avoided any chance that prior knowledge of the sample's origin might influence the analyst.

b) Reference collection of plants

The analytical technique requires reference material from plants that might occur in the diet. Throughout the study I collected specimens of grasses, attempting to get a complete coverage of all species occurring on The Garden station. These were identified with the aid of botanists at the Conservation Commission's laboratory at the Arid Zone Research Institute in Alice Springs, and at the University of New England. Wherever possible material was collected and stored in FAA as well as being conventionally pressed. Specimens were sent to the University of New England so that slides of epidermis could be prepared.

c) Epidermal reference slides

The following method was developed by C.M. Phillips to prepare reference slides.

1) The grass specimen was separated into leaf, sheath, stem and seedhead.

2) Leaf, sheath or stem material was cut (transversely) into 5 mm lengths and placed in a conical flask with a 10% solution of chromic/nitric acid.

3) The flask was heated intermittently over a bunsen burner for about five minutes, the contents being kept near simmering and being swirled around the flask.

4) After about five minutes the epidermis began to separate from the mesoderm. At that stage water was added to halt disintegration, and some drops of ammonia solution were added to neutralise the acid.

5) The flask's contents were transfered to a beaker. The epidermal fragments usually floated to the surface. Using a small brush, fragments were lifted out and placed in a small quantity of Safranin stain.

6) After a few minutes in the stain, the fragments were removed to a solution of dilute glycerine. Excess stain was allowed to leach out.

7) The fragments were mounted in glycerine jelly, taking care to prevent their folding or rolling.

8) Once the analyst was familiar with diagnostic characteristics of each part of the species, a typical specimen was photographed.

9) Black-and-white prints of the microphotographs were mounted on cards to form a permanent record of the characteristics by which the parts of each species were being recognised.

10) Seedhead material was treated in the same way, except that no attempt was made to get complete separation of epidermis from other tissues.

11) Where they differed, specimens were taken from both the abaxial and adaxial surfaces of leaves (although these were not recorded separately in the analyses). Care was taken to include, or to record the characteristics of, the edges of leaves.

d) Preparation and analysis of faecal samples

Faecal samples were prepared (by C.M. Phillips) for analysis thus.

1) The material, if in FAA, was agitated with a glass rod to ensure separation of particles. If dried, the material was soaked for 24 hours in water, then agitated.

2) Material was transfered to 70% alcohol.

3) A subsample of the material was taken and Safranin stain added to it.

4) After 24 hours the stained particles were washed to remove excess stain and were stored in 70% alcohol.

5) When ready for analysis, the material was agitated and a subsample lifted out with a Pasteur pipette and placed on a microscope slide. The sample was covered with a coverslip and examined under a microscope at magnifications generally between X200 and X400.

6) The slide was completely "read" from one side to the other, all potentially recognisable fragments being recorded. A 'potentionally recognisable fragment' was one which was large enough for the analyst to expect to be able to see the combinations of cell types, shapes, and distributions by which most parts and species could be identified.

7) Fragments differed greatly in area. The analyst kept in mind a standard unit size, and recorded each fragment as being X times this standard. This standard size covered about 100 epidermal cells of the commoner grass species.

8) If the fragment could not be identified but appeared to have characteristics that differed from all the reference material, it was photographed in the hope that it might later be identified to species and part.

9) The first 100 encountered fragments were recorded as being from monocotyledonous or dicotyledonous plants (i.e. from grasses and their allies, or from non-grass species). Only the monocot fragments were further recorded by size, species and part. From each sample, 46 potentially identifiable fragments of monocot material were recorded and identified to species, genus or genus-group if possible. Records of the analysis were made on standard data sheets.

This analytical method is painstaking and quite slow. It depended heavily upon the developed skill of the analyst and her ability to recall (and, of course, check against reference slides or photographs) the epidermal characteristics of the different parts of over thirty grass species. At most, three or four samples can be analysed each day.

2.2.2 Variation in vegetation - for chapter 4

a) Sites for vegetation assessment

To monitor changes in quality and quantity of pasture during the study 52 sites were chosen on the Hale Plain (Figure 2.7). All sites selected were assessed periodically while conducting animal transects. Scores of 1 (0-25%), 2 (26-50%), 3 (51-75%) or 4 (76-100%) for the proportions of green/dry, leaf/stem and grazed/ungrazed pasture were recorded along with the proportion of browsed/unbrowsed trees or shrubs. Biomass of pasture (expressed as dry weight grams/square metre) was estimated after training at standard sites and with reference to photographs of standard sites (see section 2.2.2.b)).

While driving along transects (used for estimation/recording of stock density) I selected sites each time the vegetation changed and when I found an area of approximately 1 ha of homogenous herbaceous vegetation (Figure 2.7 & Table 2.8). Initially I used the dominant grass as the main criterion for classification. For final analyses the classification of sites was based on the soil, landform and vegetation units of Grant (1986) (Figure 2.9).

b) Biomass (quantity) estimation training

From the 52 vegetation sites I chose 4 (Table 2.9) as standards upon which to base estimation of pasture quality and biomass (grass component) at other sites. Two of the standard sites were from land unit D, one was from C and the other G. I trained myself at these sites to produce consistent estimates of quantity and quality of pasture at all other sites. At these sites on three occasions during the study I clipped 10 one-metre-square quadrats. The weights of fresh herbage were estimated prior to clipping then checked by weighing after clipping; both fresh and dry weights were recorded. Regressions of estimated fresh weight versus actual fresh weight were calculated and used to adjust the estimated biomass of the entire 1-ha site. The corrected site estimate was then converted to dry weight using the percent dry weight data. Photographs were taken of the standard sites and biomass was estimated for other sites based on their relative difference from the standard sites. Friedel and Shaw (1987) recommend this method and it proved very useful for quick assessment of a large number of sites in conjunction with transect patrols.

c) Greenness and leafiness: Quality of fodder

Some clippings from the standard sites were sorted into leaf, stem, green and dry material as standards upon which to base site estimates of pasture quality.

d) Palatability and pasture removal

To study the relationship between grazing, distance from permanent water and species composition, I chose 15 sites (Table 2.10), 5 from each of three vegetation types dominated by grasses of varying palatability (*Enneapogon* spp., *Astrebla* spp. and *Aristida browniana*). The dominant grass of land unit C is *Enneapogon* spp. which is

Table 2.8: Sites selected to monitor changes in pasture quality and quantity. Fifty two sites were on the Hale Plain and 2 were in Mordor Pound (Wallace's Paddock) 15 km south of the Hale Plain.

no. of Sites	Unit	Dominant grass	Methods used at all sites
20*	C	*Enneapogon* spp.	Estimation of Biomass, green/dry, leaf/stem, %grazed and %browsed based on training at standard sites.
2	C	*Aristida contorta*	
5	D	*Aristida browniana*	
9	D	*Enteropogon* spp.	
2	D	*Eulalia fulva* or *Bothriochloa* spp.	
2	D	Scalded	
10	G	*Astrebla* spp. *Enneapogon* spp.	
4	F	*Astrebla* spp. *Eragrostis* spp.	
54	Total		

* 2 sites in Mordor Pound

very palatable and nutritious. The *Astrebla* spp. of gilgaied plains (land units G and F) are of medium quality, and *Aristida browniana* which is the dominant riverine grass (land unit D) has low nutritive value and is unpalatable (DPP Range Herbarium). For each vegetation type five sites were selected at distances from permanent water ranging from 0 to 9 km.

I conducted wheel-point transects to monitor changes in herb cover and height at these sites. Recorded were the species and height of herbaceous plants intersected by an imaginary vertical line drawn from each of 100 points spaced 2 metres apart along 2 parallel transects (50 metres apart). At the beginning of the study 100 points were sufficient to determine species composition but by summer 1985/86 plants were too sparse and there was insufficient time to increase the number of sample points so species

Table 2.9: Standard sites used to train myself for rapid estimation of pasture quality and quantity at other sites.

No. of Sites	Unit	Dominant grass	Methods
1	D	*Aristida browniana*	Biomass in each of 10 quadrats was estimated. Quadrats were clipped and plants weighed and dried. Estimates were compared with actual weights. In this way I trained myself to estimate biomass, and ratios of green/dry and leaf/stem at all 54 sites. Wheel-point transects for % cover, species composition and height of pasture species were also conducted at standard sites.
1	D	*Enteropogon ramosus*	
1	C	*Enneapogon* spp.	
1	G	*Astrebla* spp	
4	Total		

Table 2.10: Sites representing pasture dominated by 3 common grass species (5 for each grass species) of varying palatability.

No. of Sites	Unit	Palatability	Dominant Grass	Methods
5	C	Excellent	*Enneapogon avenaceous* *E. polyphyllus*	Wheel-point transects of 100 points were conducted to determine % cover, height of pasture species and species composition. Biomass, leaf/stem, green/dry, % grazed and % browsed were estimated based on similarity to standard sites.
5	G&F	Moderate	*Astrebla* spp.	
5	D	Poor	*Aristida browniana*	
15	Total			

composition was not determined in the later stages of the study.

e) Distance from water and pasture removal

Preliminary results from the 15 sites mentioned above (section 2.2.2.d)) indicated that there is a relationship between distance from watering point and pasture removal. For intense study of the relationship and in an attempt to rule out soil or topographic influences, 12 sites (Table 2.11) were selected all from Grant's (1986) land unit 5.1. They were chosen at distances from water ranging from 0.9 to 6.5 km. In an attempt to detect inter-paddock differences 6 sites were situated in the White Dam paddock and 6 in the neighbouring Cox Bore paddock.

2.2.3 Ground-based survey of horses and cattle - for chapters 4 to 7

Existing roads and fence-lines were combined with off-road driven transects and horse-back transects to provide a relatively complete coverage of the Hale Plain (200 km^2) (Figure 1.7). The horse-back transects crossed rugged terrain impassable to vehicles. Access roads through The Garden station were used as transects to make full use of the time available and to collect data in areas other than the Hale Plain. However, most ground-based transect work was conducted on the Hale Plain where horses were more observable and the country was least rugged. The total length of transects regularly

Table 2.11: Twelve sites representing Grant's land unit 5.1 were chosen to study more closely the relationship between pasture removal and distance from water.

No. of Sites	Unit	Dominant grass	Methods
12	C	*Enneapogon avenaceous* *E. polyphyllus*	Wheel-point transects were conducted to estimate %cover, height of species, and species composition. As for all sites pasture biomass, green/dry, leaf/stem, % grazed, % browsed were determined based on a comparison with standard sites.

Table 2.12: The area of Perry's land systems (Perry et al. 1962) visible from all Garden Station driven or ridden transects.

Land System	Total Area (km^2)	Area Sampled (km^2)	Sampling Fraction (%)
SO	114	0.1	0
HA	1219	17.3	1
BS	420	5.8	1
HU	108	2.4	2
AB	228	19.7	9

Total length of transects = 174 km

patrolled was 174 km. There were 100 km of Hale Plain transects including 22 km of horse-back transect. Sampling fractions for Perry's land systems and Grant's land units are presented in Table 2.12 and Table 2.13 respectively.

a) Period of patrol

All transects were patrolled at least once every three months for the period from June 1984 to January 1986. Transects were discontinued in early 1986 for a while to allow other work, radio-telemetry, post mortem examinations, and environmental damage surveys to be conducted. Transects were run for the last time in September 1986 just after the unusually high winter rainfall.

Patrolling of transects occurred throughout the day-light hours, commencing as early in the morning as possible. Preliminary results from transects repeated in the morning, midday and evening indicated that daily distribution of cattle varied much more than that of horses. However, because of the length of time taken to complete transects and the number of transects required to cover the study area adequately, it was impossible to restrict all transects to certain periods of the day. Care was taken when interpreting cattle distribution data because they tended to occupy feeding areas during the night and early

Table 2.13: Shows the area of land units derived from Grant's units (Grant, 1986) sampled during transects on the Hale Plain.

Unit	Total Area (km^2)	Area Sampled (km^2)	Sampling Fraction (%)
A	3.6	0.1	3
B	54.4	6.0	11
C	31.0	4.5	15
D	57.0	5.7	10
E	36.4	1.8	5
F	11.4	4.7	41
G	6.2	3.1	50

Total length of transects on the Hale Plain = 100 km

morning, congregate around watering points during the hotter part of the day and then move out to feed once more in the evening.

b) Data collection

Climatic data including the temperature, wind velocity, wind direction and cloud cover were recorded at the start and finish of each transect.

For each group of horses and cattle seen along each transect the information recorded was;

- odometer reading to determine the point on the transect,
- the distance (estimated) and direction from observer to each animal,
- habitat information for the area within 50 metres of the centre of each group (see Table 2.14), and
- information on individual activity, age, sex and condition.

Distances were checked with a range finder and I occasionally paced distances to maintain accurate estimation. I collected the habitat data to supplement and to check

Table 2.14: Habitat factors recorded for each animal group seen during transects.

Habitat factor	Classification	
Vegetation	The dominant tree, shrub and grass species within 50 metres of the group.	
Slope	The greatest slope within 50 metres of the group	
	Level	0-2 degrees
	Gently inclined	2-18 degrees
	Steep	18-45 degrees
	Precipitous or Cliffed	greater than 45 degrees
Morphology	Crest, Slope, Flat or Depression	

information derived from Grant's land-unit map. Activities recorded for individuals were grazing, browsing, walking, trotting, galloping, lying, standing and drinking. I noted whether each individual was in the sun or shade. Horses and cattle were scored on a 5-point scale for condition judged systematically with reference to body outline and protrusion of bones (Table 2.15). For the ageing technique see Table 2.16.

Pocket computer: A Sharp PC-1500 pocket computer was used for collection of data during transects. This system was well suited for horse-back transects and allowed quick transfer of data to an IBM Personal Computer for analyses.

Visible area and density determination: A visibility profile was determined for each transect by estimating, every 200 metres, the distance either side of the transect that it was thought possible to see horses or cattle. From this the visible area of each land unit was calculated. The densities of horses and cattle were calculated by dividing the number of animals recorded, each time a land unit was sampled, by the area of the sample. An estimate of the density for a land unit was calculated by averaging the sample densities.

Table 2.15: Criteria for visual classification of the condition of feral horses.

Condition class	Description
Very Poor	Virtually no muscle on bone; ribs, backbone and hips protruding markedly.
Poor	Very little muscle on bone; ribs and hips protruding obviously.
Fair	Muscle on rump and back hiding hip and backbone; ribs protruding.
Good	No bones protruding; rounded rump.
Very Good	Very rounded muscle and bulges of fat.

Overlap calculation: The method used to determine the habitat overlap between horses and cattle populations with respect to land units was as follows:

1) Firstly from estimates of mean density for land units the number of individuals in a particular land unit was calculated by multiplying the area of the land unit by the density of animals in that land unit.

2) The total number of animals estimated for the Hale Plain study area was calculated by summing the estimated numbers for each land unit.

3) The percentage overlap between horses and cattle for each land unit was taken to be the lower percentage of the two in that particular land unit (see example below for clarification).

Example (not a real situation): The study area (30 km^2) was divided into 3 land units A, B and C which had areas of 10 km^2 each and densities of 6, 4 and 10 cattle/km^2 and 10, 2 and 8 horses/km^2 respectively. The total number of cattle was therefore 200 (60+40+100) and horses 200 (100+20+80). In land unit A there were 30% (60/200) of the total number of cattle and 50% of the total number of horses. The percent overlap for land unit A was therefore 30. For B it was 10 and C 40%. The total overlap with respect to land units was the sum of the overlaps (80%). This method was recommended by Jarman (pers. comm.) and appears to parallel Kulczinski's formula (Oosting, 1956).

Table 2.16: Criteria for visual classification of horses into age classes (juveniles, sub-adults and adults). These criteria were used to determine age of horses during animal transects and whenever teeth were not available.

AGE	BODY PROPORTIONS AND GENERAL DESCRIPTION
Juveniles 0-1 years	Height usually less than 13 hands**; long legs in relation to body depth*. Not weaned and therefore still dependent on their mother for at least some food. Considered too young to reproduce.
Sub-adults 1-2 years	Height usually greater than 13 hands and less than 14.2 hands; long legs in relation to body depth; and rump higher than wither. They were not dependent on their mother's milk but generally maintained contact with their mother. Less than reproductive age.
Adults >2 years	Height usually greater than 14 hands; possessing normal adult proportions; their wither was as high as or higher than the rump. Individuals of reproductive age. Displayed sex-specific body and behaviourial characteristics.

* length of leg was estimated from the ground to the stifle; body depth was estimated from the stifle joint to the back.
** 1 hand equals 4 inches or 10 cm

Although there are a wide range of techniques the simplicity of this one made it suitable given the coarseness of the data.

Types of overlap:

1) "Overlap with respect to distance from water" refers to overlap determined for areas stratified according to distance from watering points.

2) "Overlap with respect to land unit" refers to overlap determined for areas stratified according to landform, soil and vegetation (land unit).

3) "Overlap with respect to land units and distance from water" refers to the overlap determined for areas stratified according to landform, soil, vegetation and distance from permanent watering points.

2.2.4 Social behaviour, condition and reproduction - for chapters 6 and 7

a) A variety of methods

Much of the information on social behaviour, condition and reproduction was collected during ground-based transects which were run primarily to monitor changes in the distribution of horses and cattle (see section 2.2.3). Information recorded for each group of horses and cattle seen while conducting transects included:

. group size,

. the age, sex and condition of each individual (Table 2.15 & Table 2.16),

. location and

. habitat characteristics (see Table 2.14).

I have not analysed the data for cattle for this thesis.

More detailed records were obtained at a bore where horses were relatively easy to observe as they watered. In order to monitor changes in group composition, and to determine home ranges of known individuals, I photographed groups and recorded the markings and colour of each individual. On the Hale Plain radio transmitters were attached by collars to 5 stallions in an attempt to increase the number of sightings of known individuals and to allow the recording of time-budget information. I developed methods for immobilisation suitable for central Australian conditions. These methods along with those used for radio-tracking are presented in chapter 3. These methods were further refined and used in 1988 and 1989 when eight stallions were immobilised and had radio-transmitting collars attached in the Porter's Well area to determine characteristics of home-ranges and monitor movements during mustering operations (Dobbie & Berman, 1990).

Information on the habitat selection, social behaviour, condition and reproduction of horses was obtained during visits to other areas (Tempe Downs Station, Kings Canyon, Palm Valley and the Davenport Ranges) and by involvement with the aerial surveys of the Gulf and Alice Springs areas.

b) Age determination, by body shape, behaviour and teeth

One hundred and ninety five horses were examined post mortem during a control exercise on a station neighbouring The Garden station. Remains of 116 horses trapped on The Garden station were examined post mortem at the Tennant Creek Horse Abattoir.

Ageing by tooth-wear and eruption: The standard method of ageing horses is by tooth-wear and eruption patterns. Rates of tooth-wear may vary depending on the diet and the amount of sand ingested by horses (Berger, 1986). In north America, Berger compared ages estimated by tooth-wear with the known ages of free-ranging domestic horses and found only slight differences (1 to 2 years) up until the age of about 12. For older horses age is difficult to estimate. The technique may not give an accurate absolute age but probably well reflects relative differences among individuals from a population. There is variation in the literature on ages for particular stages of tooth-wear and eruption. Table 2.17 shows the stages of tooth-wear and eruption used for this study.

Skulls were collected and aged using tooth-wear criteria to determine the age structure of horse populations at death. Horses shot during a control exercise or slaughtered at the Tennant Creek Abattoir were also aged using teeth to determine the age structure of the living population.

Table 2.17: Tooth-wear and eruption stages for determination of the age of horses. The terms for the incisors (central, lateral and corners) come from Belschner's (1982) book "Horse Diseases".

Age in Years	Tooth-wear or eruption
1	All temporary teeth have erupted and are in wear
2	Central permanent incisors appear (I_1)
3	Lateral permanent incisors appear (I_2)
4	Corner permanent incisors appear (I_3)
4	Canines emerge in males
5	Infundibula (depressions in the teeth) disappear from central incisors
6	Infundibula disappear from lateral incisors
7	Infundibula disappear from corners, hook on upper corner incisors
8	Transverse line (dental star) appears on central incisors
9	Transverse line (dental star) appears on lateral incisors
10	Transverse line (dental star) appears on corner incisors
15	Galvayne's Groove extends half way down the outside of the upper corner incisors
20	Galvayne's Groove reaches the bottom of the upper corner incisors
Age class	**Major Stages of tooth-wear and eruption**
0-2	Temporary teeth appear
2-4	Permanent teeth appear
4-7	Infundibula disappear
7-10	Transverse lines (dental stars) appear

Ageing by visual estimation: Live horses were grouped into age classes during transects using height, shape of body and behaviour as criteria (Table 2.16). The three age classes (juveniles, sub-adults and adults) were expected to reflect the following stages of development:

. juveniles were dependent on mother's milk,
. sub-adults were weaned but not reproductive and
. adults were taken to be capable of reproducing.

c) Determining sex

The ratio of males to females in the whole population, and in age and social groups was determined during animal transects, counts at bores and during post mortem examinations. The sex of skulls was determined by the presence or absence of canines. Canines are generally present in males that are older than 4 years but are absent from females and horses younger than 4.

There were a number of factors which may have biased the sex ratio data collected during transects.

. Few horses could be approached closer than 100 metres during transects. At this distance the sexes of sub-adults and juveniles were sometimes difficult to determine without a long period of observation.
. Some adult males, especially with mares, are usually easy to distinguish because of their characteristic behaviour, but others (e.g. sub-adult males in a harem group) may not be.
. Larger sub-adult males sometimes behaved and appeared similar to adult females.
. Dry or barren adult females could have occasionally been mistaken for sub-adult males.

Care was taken to determine accurately the sexes of horses seen during transects but there was not sufficient time to certify all individuals. Those for which the observer was unsure were recorded as unknown sex. If any bias is present in the data then it probably favours male adults.

d) Condition estimation

Horses were scored on a 5-point scale for condition judged systematically with reference to body outline and protrusion of bones (Table 2.15).

e) Identification of individuals

Markings and colour: Individual characteristics were recorded for 150 horses seen at or in the vicinity of Top Bore. The markings of individual horses were drawn on standard data sheets containing diagrams of a horse's head (front on), and right and left sides. In this way the size, shape and position of any white mark or distinguishing characteristic were recorded. The age, sex, type, colour, and relationship to other members of the group were recorded.

- Markings included, blazes (white face), stripes (white line down face), stars (white spot on face), patches (white markings on the body) and socks (white leg markings). Any scars or other easily identifiable characteristics were recorded.
- Age was estimated in years if possible but generally age classes (Juveniles, Sub-adults and Adults) were recorded (Table 2.16).
- Sex was recorded as male, female or unknown (2.2.4.c).
- Type was a measure of the horse's build from light (Thoroughbred characteristics), medium, to heavy (draught-horse characteristics).
- Colour categories were black, brown, bay, chestnut, grey, roan and creamy.
- Relationship to other individuals in the group included mare-foal, harem-stallion and dominant (lead) mare of a harem.

The above data were recorded in an attempt to obtain information on home range size, group composition and group stability. There was insufficient time for this type of sampling to be more than just support for the transect and radio-telemetry work. Considerable amounts of time must be spent in order to be certain of the identification of a large number of horses based on markings or colour. Prior to the use of radio-telemetry the individual characteristics of relatively few horses were learnt. Only 12 horses (4 mares, 4 harem stallions, and 4 bachelor males) could be easily recognised without reference to the piles of identification sheets and photographs.

Radio-tracking: Radio-tracking equipment is expensive, attaching transmitters to wild horses is difficult and there are inevitable equipment failures. However, valuable information on movements, time-budgets and home ranges of known individuals was gained during this study using radio-tracking. Initially radio-telemetry was used to support the higher priority transect work on the Hale Plain, to provide confirmation of inferences derived from transect work about the movement of horses and cattle. A study was subsequently set up in the Porter's Well area based mainly on the use of radio-tracking, to study movement and home range with a view to improving methods of management. Immobilisation, collaring and radio-tracking techniques (see Plate 4) are described in Chapter 3.

Hale Plain radio-tracking: Radio transmitters were fitted to 5 male adult horses. Radio-tracking allowed frequent definite identifications of transmitting individuals and their companions. It provided the means to conduct 24-hour watches of collared individuals and their groups to record the time spent at certain activities.

Porter's Well radio-tracking: Radio transmitters were attached to 8 male horses and their location determined by triangulation or direct observation. Information about group stability is included in Chapter 6. Methods and results are described in Dobbie and Berman (1990).

2.2.5 Aerial surveys - for chapters 5 and 7

Aerial surveys of The Garden station were conducted in March 1986, March 1988 and again in October 1988 to describe and detect changes in the distribution and abundance of feral horses on the station.

A Cessna 182 aircraft was navigated by reference to 1:250,000 series topographical maps and maintained at a nominal groundspeed of 180 kilometres per

a) c) d) e) f) g) h)

Plate 4: Porter's Soak was the best place for darting but horses often drank out of darting range (a) and no horses visited Porter's Soak for 1 or 2 months after river flow (b). Tranquillising horses, attaching radio-transmitters and observing radio-marked groups was a very difficult process. If conditions were suitable, horses drank in darting range, my aim was good (c), the dart functioned and sufficient drug was injected (d) we were able to attach a collar (e & f). "Lucky six" was successfully immobilised (c), blind folded and legs tied while the collar was attached (d) and was up and away 10 minutes after darting (e). Each attempt to collar horses presented new problems. "Pirate" is shown to be wet in photo (f) just after collaring because he went to sleep in the water. Photo (g) shows "Fat Black Brumby" and his pregnant mare avoiding the trough and drinking at Top Bore overflow, almost out of darting range and not presenting their rump or shoulder as targets. "Athol" was handy transport (h) for locating collared horses.

hour and a nominal height of 76 metres (250 ft) above ground level. The two rear seat observers each scanned separate transects with a nominal width of 250 metres.

The station was surveyed by 8 transects, oriented north-south, 5 kilometres apart and divided into 5 kilometre segments to create a square-celled grid with 81 cells for density mapping. Horses, cattle, donkeys and kangaroos were counted and population estimates were generated by the ratio method (Jolly, 1969). Three experienced observers were used during each survey. Comparison of left and right observer counts of groups of horses on The Garden station (1986, 1988 surveys) showed no significant difference. Their counts could therefore be combined for estimate of population size. The front right observer and the rear right observer co-ordinated to collect data for determining a double-count correction factor to compensate for visibility bias. The bias correction factor was determined using the model employed by Caughley and Grice (1982) for emus.

The front right observer rated each grid cell for 9 environmental types - sand plain spinifex, sand dune spinifex, spinifex hills, grassy hills, scrubby hills, grassy plains, scrubby plains, riverine, and gibber plains. Rabbit warrens were also rated. The rating was based on a four rank system - many, few, trace and none. Both left and right rear observers counted all animals listed above and the rear right observer recorded radar heights each time he recorded a group of animals. The rear right observer could see the instrument panel by looking through the gap between the front seats. See Table 2.18 for comparison of rear left and right observer results.

Calibration of the relationship between indicated radar height and actual strip wid th following the procedure of Jolly and Watson (1979) took 30 minutes. Surveys commenced at approximately 0900 hours after calibration, and counting time was abo ut 3 hours. Total time in the air including calibration and ferry time was about 4 hours for each survey.

Table 2.18: Comparison of left and right observer counts of groups of horses for The Garden station aerial surveys (1986 and 1988).

Survey	Proportion of contribution to total count of horse groups			
	Left observer		Right observer	
1986 March	41%	(21)	59%	(30)
1988 March	56%	(24)	44%	(19)
1988 October	32%	(8)	68%	(17)
χ^2=4, df=2, P=0.13				

2.3 Data collection in other areas - for chapters 6 to 8

a) Live horses

Tempe Downs Station and the area north of Kings Canyon were visited 6 times during the study. The first trip was with K.A. Johnson in March 1984 when we drove along the Petermann Creek to Farrer Spring (see Figure 2.10). Later that year I walked with CCNT Ranger David Scammell across from Bagot Spring to Petermann Pound and then in February 1985 with both P.J. Jarman and K.A. Johnson we drove past Farrer Spring to Petermann Pound then walked over into the eastern end of the Dry Creek Valley. I explored and set up vegetation monitoring sites in the Dry Creek Valley with CCNT Ranger Alan Anderson on horse-back (12-14 June 1985). I flew in a helicopter with assistant Jill Smith along Dry Creek Valley, Petermann Pound and the 19-Mile Valley in November 1984 to determine the distribution of horse groups in the valleys. I recorded information on all horse groups seen during these trips.

I drove to the Finke Gorge-Palm Valley area (130 km south west of Alice Springs) on 4 occasions and data on group size, age, sex and condition were recorded for all horse groups seen. Data were also collected for horses of the Davenport Ranges 350 km north of Alice Springs. These visits allowed collection of information on group size and composition, age structure and condition to see if data from The Garden station were consistent with other areas in central Australia. The rain that fell in spring 1985 on The Garden station failed to fall around Kings Canyon. Observation of horses under conditions of extreme drought were possible in the Kings Canyon area at Farrer Spring, Dry Creek and 19-Mile Valleys in 1985 and early 1986.

b) Dead horses

Only eighteen skulls were found on The Garden station, some of which may have been from horses shot for pet food but I am uncertain of the reasons for death. To supplement The Garden skull collection skulls were sought elsewhere. In the dry conditions of 1985 and early 1986 many horses died of starvation or thirst in the Kings Canyon area. Seventy three horse skulls were collected by Mark Fosdick from near Farrer Spring and 41 by members of the Operation Raleigh Expedition from the 19-Mile Valley. Mark Fosdick also collected 17 skulls from the Ellery Creek 70 km west of Alice Springs.

2.4 Post mortem examinations - for chapter 7

a) Horses from The Garden station

Horses were trapped on The Garden station at Marble Bore, Pinnacles Bore and Southern Cross Bore in July 1985. They were transported 500 km to Achilles Meats Horse Abattoir at Tennant Creek for slaughter. The manager of the meat works Mr Bill Synnot kindly allowed post mortem examination of the heads, lower legs, and internal organs of The Garden station horses. The remains of 116 horses were examined. Information was recorded before slaughter and an attempt was made to relate post mortem data to data from particular individuals examined before death. However, inspection time for the carcasses varied causing the order of appearance of heads, legs and organs to differ from the order of killing. Information recorded prior to slaughter was:

. age class,

. sex,

. condition determined visually,

. height at the wither and type (see section 2.2.4.e).

Information recorded post mortem was:

. age (years) by tooth-wear and eruption,

. sex of heads by presence or absence of canines,

. sex of reproductive organs and

. the length of foetus (tip of nose to butt of tail) if present.

b) During a control exercise on Loves Creek station

In May 1986 a control exercise was conducted on a station neighbouring The Garden station 35 km south east of the Hale Plain. Of the 2,000 to 3,000 estimated total population 1,986 horses were shot. Ten percent (195) of the shot animals were examined post mortem. Data recorded were:

. age (years) determined by tooth-wear and eruption,

. sex,

. height at wither,

. type (heavy, medium or light horses),

. visually determined condition,

. for mares, presence or absence of foetus and/or milk,

. foetal sex and length (tip of nose to butt of tail),

. location and

. general comments about parasite loads, and position of bullet holes.

Photographs were taken of teeth to check ageing technique and of the bullet holes as evidence of the accuracy of the shooters. A helicopter was used to transport the post mortem team between carcasses. The time taken to collect the above data was about 6 minutes per horse after a day's practice (not including flying time).

2.5 Kings Canyon area: Operation Raleigh - for chapter 8

The Dry Creek Valley in the Kings Canyon Area is one of the few areas in central Australia where there are horses but not cattle. The area was selected to look at the environmental impact of horses alone, and to see if the impact differed from that of horses and cattle together. Since vast areas had to be covered P.J. Jarman arranged for an Operation Raleigh team to help collect data.

a) Personnel

Most of the data obtained in the Kings Canyon Area were collected during the six week Operation Raleigh Expedition. The people involved with the Operation Raleigh Feral Horse Project included venturers, army personnel and biologists from the University of New England. The venturers were young people from all over the world, mainly the British Isles. The army personnel provided the logistic support (i.e. transport and camping) as well as taking part in scientific work. There were about 30 venturers who chose to work on the feral horse project. Half of these worked the first 3 weeks and the other half worked for the remaining 3 weeks of the project. The biologists acted as leaders and also helped with data collection.

Other data were collected during 4 ground surveys and 2 aerial surveys prior to the Operation Raleigh Expedition and an aerial survey in 1988. These surveys were conducted to determine the distribution of stock and watering-points, and to test sampling techniques.

b) Transects

The valleys (from 3 to 5 km wide) were surveyed along transects from side to side recording animal signs, vegetation and soil characteristics. Groups of 10 transects (which we called runs) were located at approximately 5 km intervals along each valley (Figure 2.10 & Figure 2.11). Each transect was positioned at right angles to the direction of the valley and located parallel to and 50 metres from its nearest neighbour (Figure 2.11). Each transect was surveyed by a single pair of observers that commenced along a given compass bearing determined at the beginning of each run. Each pair attempted to keep to this bearing and remain parallel to and 50 m from the nearest neighbouring pairs. Each belt of 10 transects (i.e. each run) was 450 m wide. At approximately 200 m intervals (measured by stepping) along each transect a circular sample area (15 metre radius) was searched and the data indicated in Table 2.20 were recorded. While walking

200 m along the transect between sample areas, more data (Table 2.19) were recorded. In Nineteen Mile valley and Dry Creek valley, 2087 and 1085 circular sample areas were searched respectively.

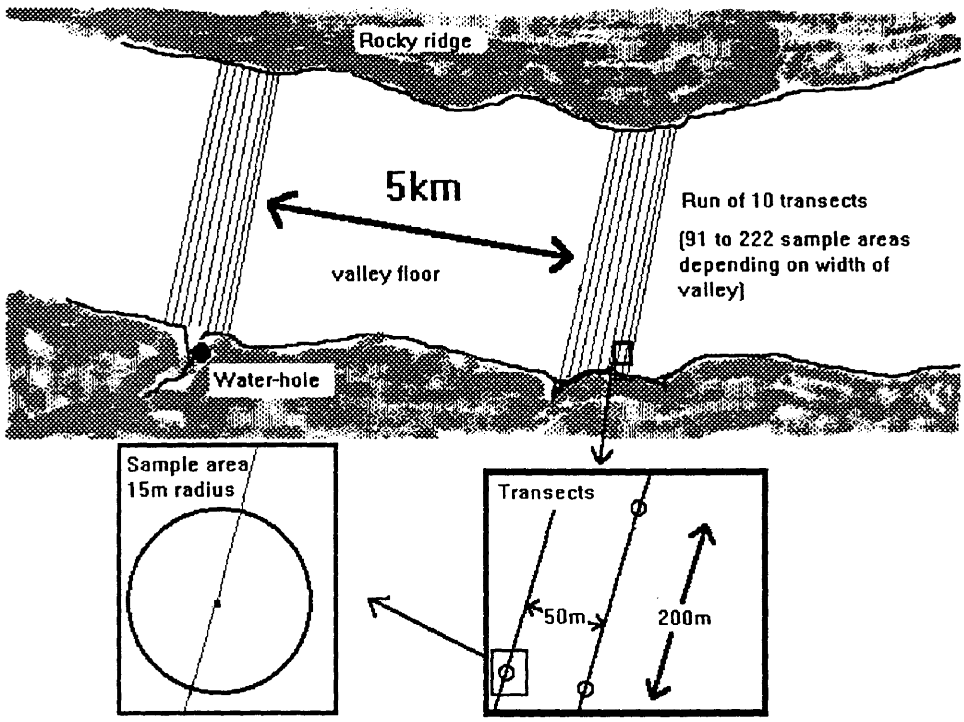


Figure 2.11: Diagram showing transect runs and circular sample areas. The section between sample areas was measured by stepping. Data were collected both in sample areas and along 200 m step sections.

Table 2.19: Type of data recorded during transects by Operation Raleigh personnel. Attributes were recorded along a 200 m line measured by stepping between circular sample areas (15 m radius).

Attribute	Description
Gully Erosion No.:	Number of gullies walked across. A gully was defined as an actively eroding watercourse or channel.
Gully Erosion Steps:	Number of steps in or across eroded gullies.
Scald Erosion Steps:	Number of steps across scalded ground. Scalding occurs where a sandy surface horizon is removed by wind and water erosion, exposing a surface-sealing clay-rich subsoil.
Pads:	Number of pads (stock trails) walked across.
Dung Piles:	Number of dung piles seen within 15 m either side of the transect. Dung piles are piles of faeces resulting from stallions defecating on the faeces of other horses.

Table 2.20: Type of data recorded during transects conducted by Operation Raleigh personnel. Attributes were recorded in 15 m radius circles placed 200 m apart along the transects.

Attribute	Description
Soil Depth (penetrability)	A graduated L-shaped steel rod (12 mm diam.) was used as a soil depth indicator. Soil depth (cm) was the depth the peg could be pushed into the ground.
Horse Dung (Brown)	Horse dung that is not grey, mainly brown, but can be black or green. The number of defecations in the circle was recorded.
Horse Dung (Grey)	Old dung, usually grey in colour. The number of defecations in the circle was recorded.
Horse Dung Piles	The number of piles in the circle.
Cattle Dung (Brown)	The number of brown cattle defecations in the circle were recorded.
Cattle Dung (Grey)	The number of old, grey cattle defecations in the circle.
Camel, rabbit, macropod dung	0 - no dung of that type in circle 1 - one defecation in circle 2 - more than one defecation
Horse, cattle, camel and other tracks	0 - no other tracks present in the circle 1 - old tracks present in the circle 2 - fresh tracks in the circle Other animal tracks were identified if possible.
Slope:	The greatest slope within the circle was estimated and recorded, using the following categories: 0 - flat ground (<2degrees) 1 - gentle slope (2-19degrees) 2 - steep (19-45degrees) 3 - cliff (>45degrees)

Continued next page

Table 2.20 Continued

Attribute	Description
Soil Size	The dominant soil particle within the circle was determined and its size estimated, using the following scale: 0 - clay or silt 1 - sand 2 - gravel 3 - small rocks (<6 cm diameter) 4 - large rocks (>6 cm diameter)
Gully Erosion Steps	One worker walked the circumference of the circle and recorded the number of steps which were in or across gullies.
Scalding Proportion	A visual estimation was made, to the nearest 10%, of the area of the circle which was scalded.
Herb Cover	A visual estimation was made, to the nearest 10%, of the area covered by grass and forbs within the circle.
Trees	The number of plants greater than 2 m tall were recorded.
Shrubs	The number of woody plants less than 2 m tall were recorded and an approximation, to the nearest 10%, of the area of the circle they covered was recorded in runs 4-12 in 19-Mile Valley.

c) Transect data

Transect data were recorded by one member of each pair on proforma data sheets. Pairs of workers were then responsible for entering their data onto a Sharp Pocket Computer to enable rapid transfer of data to larger computers for analyses.

The data sheets were explained to the Operation Raleigh and Army volunteers item by item using examples in the field wherever possible. Photographs and real examples of animal tracks, dung and erosion types were available to the workers to help with classification. Data items were recorded following the rules set out in Table 2.20. Biologists were with the venturers for consultation during transects.

The intensity of use of areas by animals was inferred from the abundance of tracks (hoof prints) and dung. The type of soil may determine the ease of detection of tracks but there are few places where the soil is too hard for horses or cattle to make hoof prints. Tracks tell us where horses have stood, walked, trotted or galloped during the past month or two. Fresh dung indicates more recent distribution of horses than old dung but the age difference is not known exactly and may vary depending on climatic conditions. The distribution and abundance of dung tells us where animals have done most of their defecating during the past 1 to 2 years. Faeces had kept very well in the area because there had been very little rain since January 1984. I had been monitoring the decay of marked faeces on The Garden station for 18 months.

d) Tests of accuracy and consistency

The first day of work for each group of venturers was spent explaining the sampling procedures - both why and how they were to be done. Trial sampling runs and tests of accuracy and consistency between venturers were conducted. For the variables tested the majority of decisions were correct. A few people confused macropod and cattle tracks. The colour of horse dung was occasionally wrongly classified. Scores for dominant soil particle size were the most inconsistently recorded. Some people were averaging the soil particle size while others based their estimate on a very small part of the sample area.

e) Statistical analyses

Linear correlations were done using all combinations of variables (Table 2.20) to give an indication of relationships between variables. Results of linear correlations must be treated with caution especially where non-continuous variables are involved. However, preliminary analyses using more sophisticated techniques (multivariate methods of classification and ordination) supported the linear correlation results and failed to provide additional information.

Chi-squared analysis and coefficients of association were calculated to determined the level of association between horse, cattle and macropod signs.

The percentage of each run (group of 10 transects) with gully hazard and/or scald hazard was determined for the 13 runs across Nineteen Mile valley. Percentage data were arcsin transformed and simple linear regressions done for the erosion hazard data against erosion data and distance from permanent water.

f) Water-hole search

Thorough searches for water-holes were made by members of the expedition particularly P.J. Jarman who recorded descriptions of 14 water-holes noting signs of stock and wildlife use. A helicopter survey of the area in April 1988, just after good rain, was conducted to search for other important semi-permanent water-holes which may have been missed during the dry conditions of 1986.