CHAPTER 7
POPULATION PROCESSES

7.1 Introduction

In 1979 the Board of Inquiry into Feral Animals (Letts et al., 1979), using an estimate of 20,000 to 50,000 feral horses in the Northern Territory, did not regard the species as a significant pest. Their population estimate was based on McKnight's (1976) questionnaire interview survey which he commenced in 1966 and completed in 1971. Since then central Australia has had the best 10 years of rainfall on record (1974 to 1984) (see Figure 1.3) and there is evidence from scientific survey and public reaction to suggest the run of good seasons may have caused marked increases in feral horse density. Many population processes, such as rates of birth and death are density dependent; so is the process of obtaining funds to conduct research into the processes of animal populations.

In the early 1980s, pastoralists and conservationists expressed increasing concern regarding the impact of feral horses. Aerial survey of the Victoria River District and the Top End of the Northern Territory in 1981 indicated there were 90,000 feral horses in those areas alone (Graham et al., 1986), many more than previously thought. Furthermore, methods of feral horse control received heightened attention from animal welfare groups and the potential for a conflict of interests was imminent. As a result, in 1984 the Conservation Commission of the Northern Territory began funding and conducting research. The density of feral horses had perhaps reached the threshold level at which funding becomes available.

Aerial surveys in 1984 to determine the distribution and abundance of feral horses in the Alice Springs and Gulf regions of the Northern Territory combined with the 1981 surveys produced an estimate of 206,000 (Bowman, 1985), more than 3 times McKnight's maximum estimate of 60,000 (McKnight, 1976) for the Northern Territory population. Is it possible that the Northern Territory feral horse population increased from 60,000 to 206,000 in 12 to 13 years or was the apparent increase a result of different sampling techniques? I expect that many of McKnight's questionnaire respondents underestimated the number of horses on their property as this is the tendency for such guesses (Caughley, 1977). However, we have no better estimate for that time and we cannot judge the validity of apparent changes in feral horse populations without understanding the population processes that may be specific to Australian conditions.

Arid Australia appears to be particularly favourable for long-term survival of feral horses due to lack of diseases (Letts et al., 1979) and predators, suitable breeding conditions and sparsely settled areas (McKnight, 1976). Properties in central Australia were originally set up for the production of horses for sale as army remounts. Although this trade stopped 40 years ago horses are today exported as meat for human consumption. An abattoir was established to process horses at Tennant Creek in 1984 and another exists at Peterborough S.A., both being able to draw on N.T. horses. How many feral horses can these enterprises expect to be able to harvest on a sustained basis? How many horses must be removed to keep the population below a level acceptable for pastoralists and conservationists? How often must control be conducted? To answer these questions we need to know reasonable estimates for the "primary population parameters" (Krebs 1985); birth rate, mortality, immigration, and emigration. We need to know the factors that cause these parameters to change and how much they are likely to change.

This chapter presents information on the processes of reproduction, growth to maturity and mortality in the population of feral horses in central Australia. I also attempt to identify the most important population parameters and show how these are influenced by seasonal variations in resources. I derived estimates of the important parameters necessary for predictive models of feral horse population change.

7.2 Methods

No feral horse research has previously been conducted in areas as remote and rugged as the central Australian feral horse habitat. When this study began I did not know how best to obtain the population statistics in such expansive and rugged areas. For this reason data were collected opportunistically from a variety of sources. Chapter 2 describes classification and data collection methods in detail.

Very few horses could be individually identified and regularly located. The horses could not generally be approached and observed without them taking fright and galloping out of sight. Not all horses seen could therefore be classified into age and sex classes. Information was obtained from skulls of horses found dead, from horses classified during aerial survey, and from post mortem examination of carcasses at an abattoir and during a control shoot. The harvest and control exercises that provided horses for post mortem examinations were conducted primarily to remove horses from the cattle stations to reduce the grazing pressure, and not specifically to collect data for this study. Methods used and the range of information collected were constrained somewhat so that the harvest/control exercises were not interfered with. For horses shot from a helicopter, with practice I could conduct post mortem examinations in 6 minutes (not including flying time). I was transported by helicopter from horse to horse following closely the helicopter containing the shooter so as to locate the horses easily and examine them before they began to putrefy too much. In addition to collecting information pertinent to this chapter I was required to assist a veterinarian in evaluating the humaneness of the shooting. This involved recording the number and location of bullet holes and estimating time from shooting to death. In three days 195 horses were examined post mortem after being shot from a helicopter. There were a total of 1990 horses shot during the exercise.

It was not simple to conduct post mortem examination of horses at an abattoir without interfering with normal processing operations. Horses were assessed for body condition as they stood in the race awaiting slaughter. After slaughter the heads and reproductive tracts were examined to determine age, pregnancy rate and foetus sex and size. Unfortunately the heads, innards and body condition estimates could not be matched for any one horse because they unexpectedly proceeded through the butchering process at different rates and came out in a different order to the way they went in. Veterinarians were examining some heads but not others, causing the sequence to be disrupted.

7.2.1 Birth and death

Data from ground-based transects, post mortem examination, and collection of skulls are all used in this chapter to determine birth rates, season of birth, changes in body condition, age structure, sex ratio and reasons for mortality. A detailed description of methods appears in Chapter 2.

Life tables and fecundity tables were developed by conventional demographic methods described by Caughley (1977) to estimate age-specific survival and fecundity rates. There was considerable variation in the number of horses in each age class. For life tables the age structure was smoothed using a fitted log-polynomial curve (Caughley, 1977). I also used the Chapman-Robson method (Chapman & Robson, 1960) which tests statistically whether there is constant survival through all age classes and provides iterative procedures for irregular age distributions. The precision of the estimated survival rates can also be calculated, an advantage over conventional life table approaches. A further difference between the Chapman-Robson and conventional life table approaches is that the latter computes age-specific rates while the former involves an average rate for a age segment.

7.2.2 Harvest and escape or release

Number of horses removed and location of removal were obtained from The Garden station and Department of Primary Industries and Fisheries records. No horses were released or escaped into the studied feral population during the study.

7.2.3 Immigration and emigration

Some feral horses in the study area were identified by colour and markings, and radio tracking collars were attached to 4 stallions on the Hale Plain and 8 stallions in the Porter's Well area (Dobbie & Berman, 1990) to determine size of home range and distance moved (see also Chapter 3). Ground-based transects also indicated the location and distance moved by the herd of horses (see Chapter 6 for definition of herd). Data obtained from these three techniques were used to assess the importance of immigration and emigration relative to other population parameters. The initial attempt at radio tracking encountered many problems associated with immobilisation of horses for collaring and inadequate tracking equipment. Frequently I was unable to receive signals from collared horses. Some appeared to have vanished for up to two or three months before their signal was received again. There was no way of knowing whether this was caused by horses moving out of the study area or by transmitter failure. However, on one occasion while driving along a transect I came across a stallion with a transmitter which was not working. The transmitter restarted when the stallion shook his head. So one transmitter at least was malfunctioning. With more sensitive receivers and considerable expertise in immobilisation of horses gained through experience, a subsequent more detailed study of the movement and home range of horses (Dobbie & Berman 1990) indicated immigration and emigration to be relatively unimportant at least under the conditions experience during the study.

7.2.4 Population verification

I was an observer during three aerial surveys of The Garden station conducted March 1986, March 1988 and October 1988. Survey methods are described in Chapter 2. Using derived population parameters the expected changes in population size from 1986 to 1988 were plotted and checked for credibility using the estimates from aerial survey.

7.2.5 Statistical methods

To compare age structures for feral horse populations sampled in different times and places Chi-square analysis was employed. Since it is not valid to have more than 20% of the expected values less than 5, older age classes were pooled. I used one-tailed Kolmogorov Smirnov tests to determine whether males were in better condition than females and whether the horses examined post mortem in 1985 were in better condition than those examined in 1986. Kruskal-Wallis nonparametric one-way analysis of variance was used to test whether condition of adult horses differed over 6 time periods. If a difference was detected then I used Multiple Comparisons to determine which periods were responsible for the difference (Zar, 1984 page 200).

7.3 Results

Information about every horse seen by me (2,583 records) during 1984, 1985 and 1986 was recorded and 68% were classified into adult, sub-adult and juvenile age classes. The remaining 32% were seen too fleetingly for certainty in classification. The majority of records (1,595; 63% classified by age) were taken during regular ground-based transects on the Hale Plain. There were 452 (56% classified by age) records obtained for horses seen in other areas of The Garden station and 122 records obtained near Finke Gorge, Kings Canyon (Dry Creek) and in the Davenport Ranges (Table 7.1).

7.3.1 Frequency of foaling

Thirty four (55%) mares (>2 years old) were pregnant and 31 (50%) were lactating in the sample of shot horses. Seventeen (27%) were pregnant and lactating, 17 pregnant and dry, 16 open (not pregnant) and lactating and 14 both open and dry (6 of these were 3-year-olds). Of the 2-year-olds (6) none were pregnant although 1 was recorded as lactating. There was no difference in pregnancy rates between lactating and non-lactating mares (Table 7.2).

Table 7.1: Proportion of horses classified into age classes for areas in central Australia.

Location	Adults		Sub-adults		Juveniles		Total
Hale Plain	661	0.66	161	0.16	182	0.18	1,004
Mordor Pound	54	0.73	9	0.12	11	0.15	66
Porter's Well area	146	0.73	21	0.11	32	0.16	199
Finke Gorge	15	0.68	4	0.18	3	0.14	22
Dry Creek	41	0.80	5	0.10	5	0.10	51
Davenport Rge	17	0.74	3	0.13	3	0.13	23

Table 7.2: Number of adult females (age>=3 years) in different reproductive and body conditions as examined post mortem in May 1986.

Condition	Preg Lact	Dry Open	Preg Dry	Lact Open
Good (4)	9	3	10	2
Fair (3)	6	5	7	9
Poor (2)	1	6	0	5
Total	16	14	17	16

7.3.2 Growth to maturity

Figure 7.1 indicates that central Australian feral horses attain maximum height at the withers by 4 years of age.

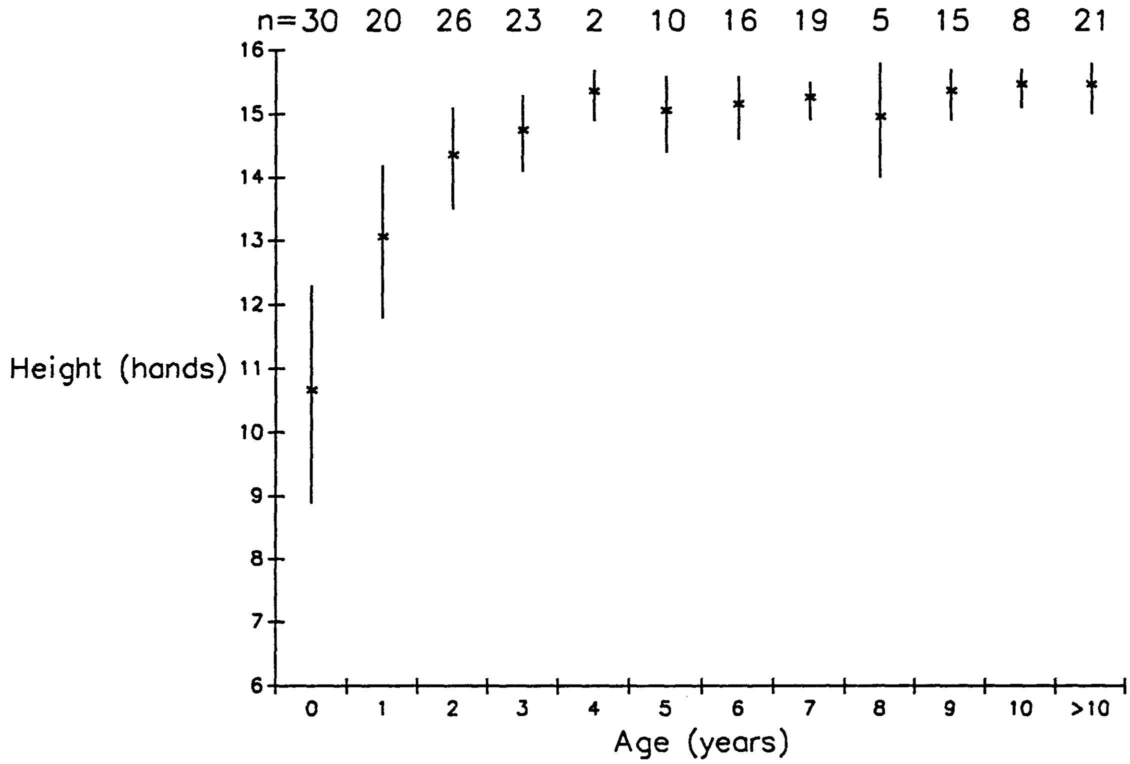

Figure 7.1: Height of feral horses measured from hoof to withers (1 hand = 10.16 cm) for horses examined post mortem (1986). Standard deviation (vertical lines), means (*) and the number of horses (n) in each age class are shown.

7.3.3 Factors affecting fecundity

a) Variation in habitat quality

Pooling all transect records for each area (Figure 7.2 and Table 7.1) indicated slight differences between areas in proportions of adults, sub-adults and juveniles. The proportion of Juveniles ranged from 0.10 in the Dry Creek valley to 0.18 on the Hale Plain. The proportion of sub-adults ranged from 0.10 in the Dry Creek valley to 0.18 at Finke Gorge (n=22). There was no statistically significant difference between the proportions of adults, sub-adults and juveniles for the 6 areas tested (χ^2=10.9, df=10, P=0.37). However, plotting the areas in order of increasing water availability indicated that areas like Finke Gorge and the Hale Plain with greater availability of permanent free water, and deeper and perhaps more fertile soil, had the smallest proportion of adult horses in the population (Figure 7.2). This may be the result of influence of habitat quality on birth rate or juvenile and sub-adult survival rate. Differences between areas in age structure may also result from the influence of distance to drinking water or differences between areas in seasonal conditions. I have not attempted to identify the major factor; I simply want to point out that samples from different areas may have different proportions of adults, sub-adults and juveniles perhaps reflecting different birth or survival rates. Despite this, the major impression gained from Figure 7.2 is how similar populations are. All have 10-20% juveniles, 10-20% sub-adults, and 65-80% adults.

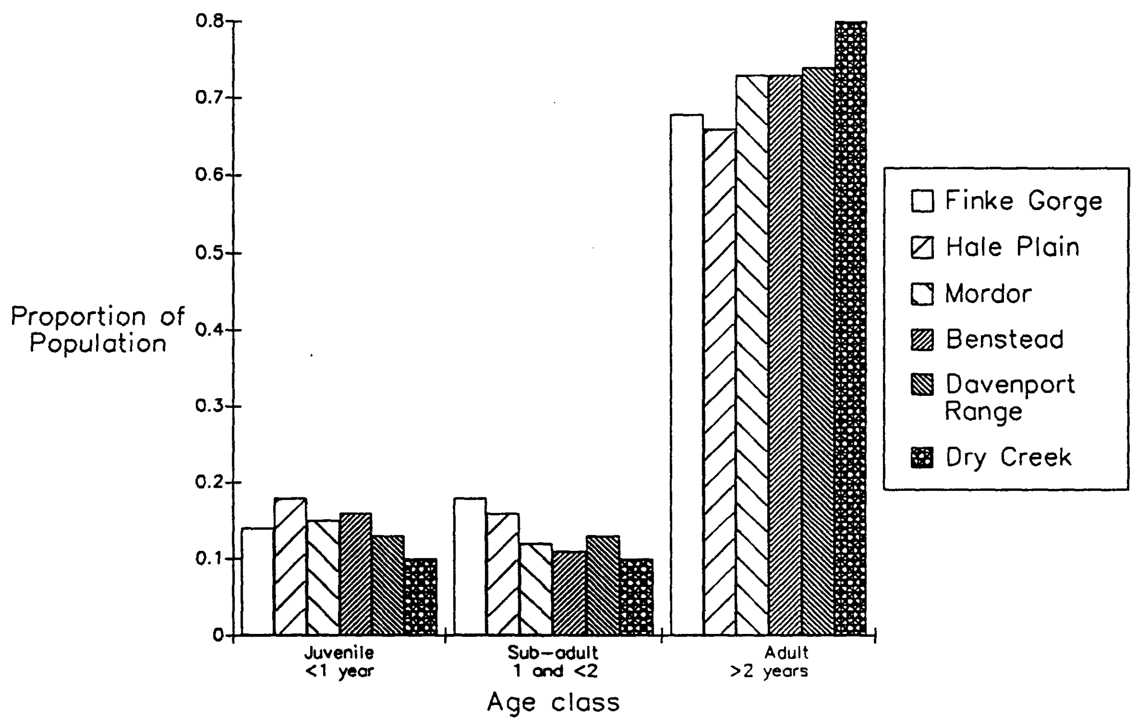

Figure 7.2: Proportion of horse populations in age classes for 6 areas in central Australia. Areas are ordered to show apparent positive relationship between availability of drinking water and the proportion of young horses.

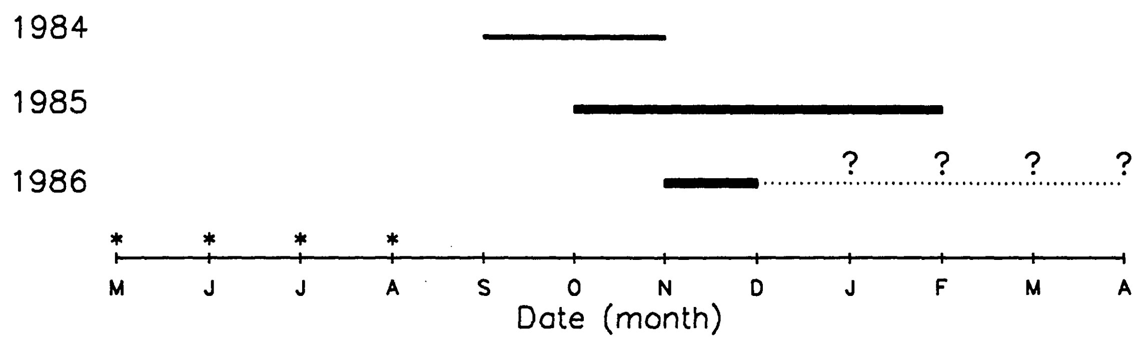

Figure 7.3: Seasons of birth for three years of study 1984-86 determined from field observations of new born foals. * represent months where no new born foals were seen during transects. ?— no field work conducted.

b) Season of birth

Figure 7.3 shows the seasons of birth for 1984, 1985 and 1986 based on field notes of sightings of new born foals. Unfortunately, new born foals were recorded as juveniles (<1 year old) so I cannot present the frequency of births per month from transect records. Figure 7.3, however, indicates that the season of birth was delayed in 1985 and 1986 compared to 1984. Dry conditions during the 1984 and 1985 seasons of birth (seasons of conception) may have caused a delayed season of birth in the following years. More detailed records of the occurrence of new born foals are required to confirm this. Figure 7.4 actually indicates the 1986 season of birth to be earlier than the previous years; however, the difference was not statistically significant. To produce Figure 7.4 for pregnant mares trapped in August 1985 and shot in May 1986 I measured the foetal length (tip of nose to top of tail). These measurements were used to estimate the expected date of birth and provide a quantitative illustration of the predicted season of birth for 1985 and 1986. A formula for conversion of foetal length to age was obtained from Kamal (1985) who measured various proportions of foetuses to find suitable estimators of foetal age. These predicted seasons correspond approximately with months when new born foals were observed on The Garden station.

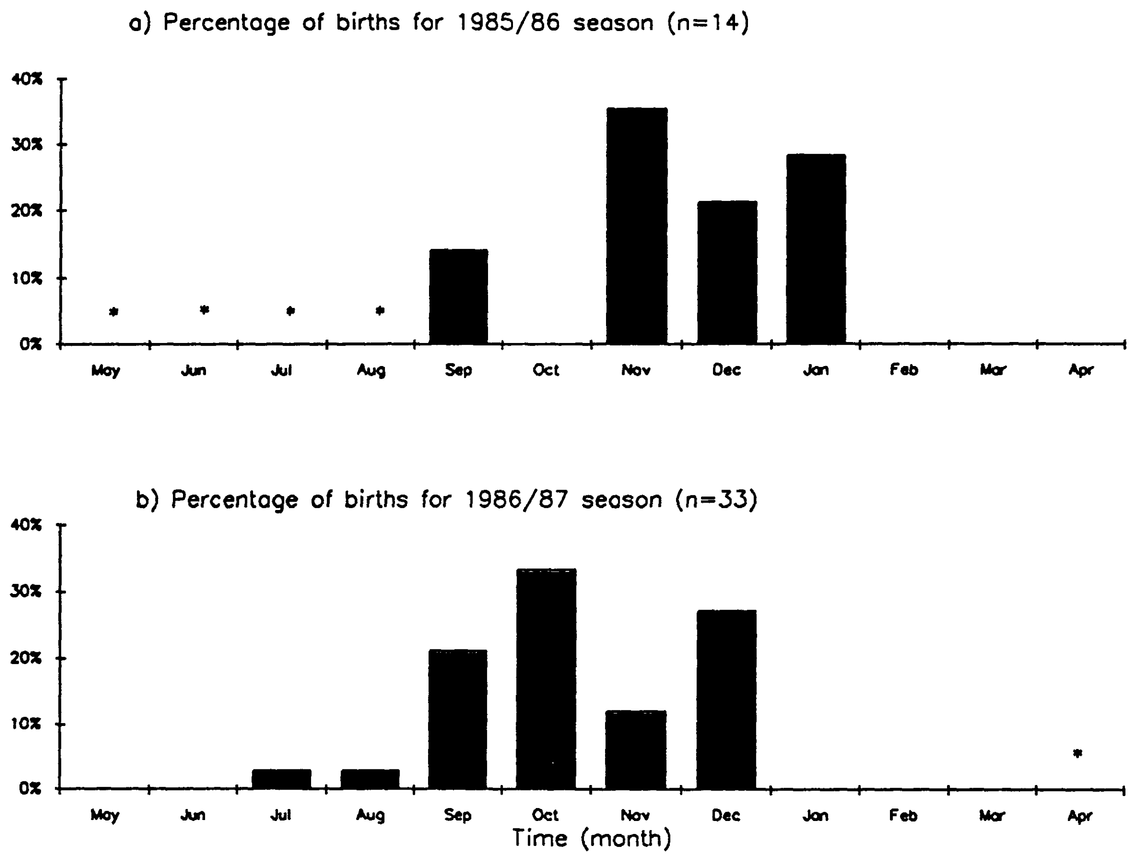

Figure 7.4: Proportion of births per month estimated from post mortem measurement of foetus of a) horses trapped on The Garden, August 1985 and b) shot on a neighbouring station, April 1986 (* months not sampled).

c) Body condition

i) Post mortem data

To aid interpretation of possible differences in pregnancy rates of two samples of horses examined post mortem, visual estimation of body condition (see methods Chapter 2) was compared for the two samples. In August 1985 17% of females and only 3% of males were in poor condition for a sample of 61 horses trapped on The Garden station. Seventy nine percent of the males in the trapped sample were in good condition compared to 35% of females. Similar sex differences were obtained for a sample of 195 horses shot 8 months later on a neighbouring station during a control exercise (May

1986). As for The Garden station sample more females were classed in poor condition (15%) than males (1%) and more males were in good condition (67%) than females (51%). The frequency distribution of condition scores for females was significantly different to that for males for 1985 but not 1986 (Table 7.3). The frequency distribution of condition scores for males or females did not differ significantly for the 1985 and 1986 samples. I assume therefore that the two samples were from populations of horses with the same overall body condition. It would have been nice to compare the condition of female adults for both years but I was unable to match age with body condition for the 1985 sample. Age determination was conducted after slaughter; however, the heads were unexpectedly in a different order to the one in which the horses were assessed for body condition before slaughter, because veterinarians had selected some heads for inspection but not others after slaughter. Thus condition could not be linked to an individual's age. Unfortunately I was not in full control of the data-gathering situation. I was "data gleaning" in the midst of a chaos of vets and the production-line methods of the Abattoir.

Table 7.3: Results of Kolmogorov Smirnov test for difference in the distribution of frequency of condition scores for two samples of horses examined post mortem (September 1985 and May 1986).

Hypothesis	One tail P	Conclusion
1985 male=female	0.004*	Males were in better condition than females in 1985
1986 male=female	0.086	Indication that males were in better condition than females in 1986
Female 1985=1986	0.766	Condition did not vary between years for females or males
Male 1985=1986	0.376	
* Statistically significant at 5% level, therefore reject hypothesis		

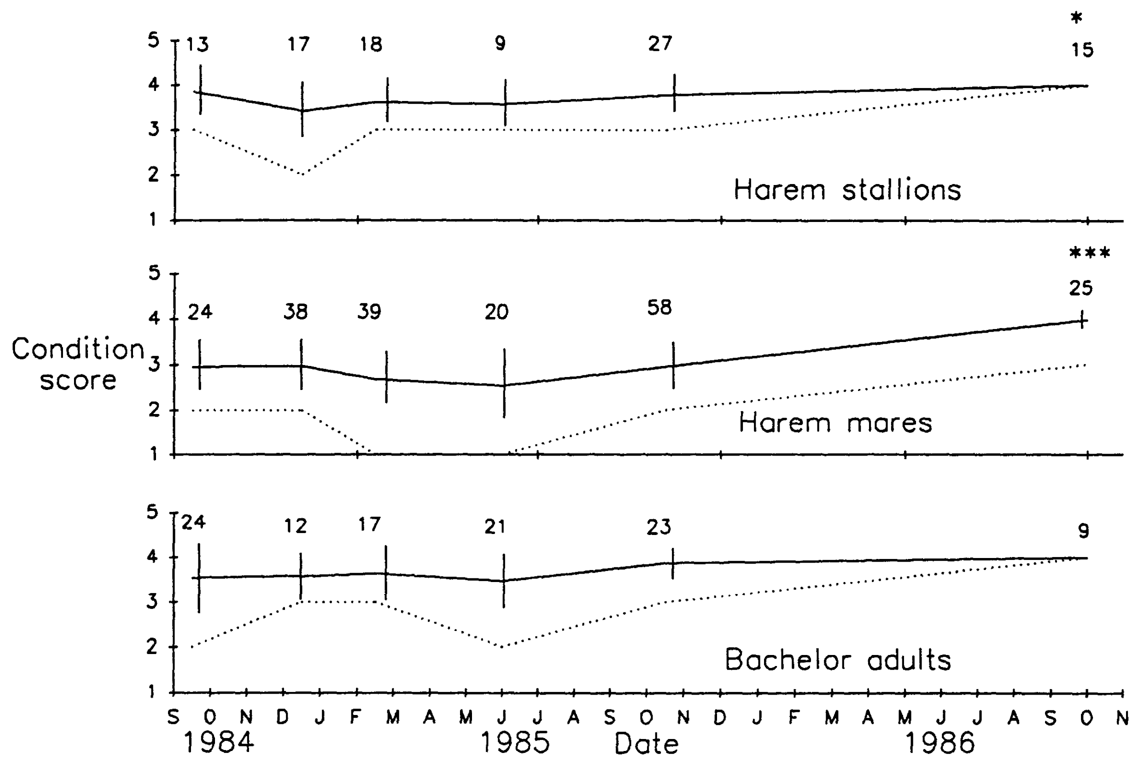

Figure 7.5: Condition of harem stallions, mares, and bachelor adults recorded along transects on the Hale Plain. The means (___) ±SD (|) and the minimum score (...) are shown. *P<0.05, ***P<0.001

ii) Transect data

Horses of all ages from both harems and bachelor groups were in better condition after the rains of winter 1986 than at any other time during the study. The poorest horses were seen in 1985. Figure 7.5 shows harem females to have been recorded in poorer condition than harem and bachelor stallions. Apart from some mares being very poor in winter 1985 and harem adults recorded in spring 1986 being in better condition than at any other time (Figure 7.5 and Table 7.4) there was very little change in the distribution of condition scores during the study. There was no statistically significant change at all in distribution of body condition scores during the study for bachelor male adults (Table 7.4). Table 7.4 shows results of Kruskal-Wallis nonparametric one-way analysis of variance.

Table 7.4: Change in condition of adult horses during the study. Data were collected by patrolling transects on the Hale Plain and were divided into 6 sample periods (see also Figure 7.5).

Nonparametric AOV to see if the condition of adult horses differed over time.		Multiple comparisons to determine between which periods the differences occurred.		
Social class	Probability of no difference between periods	Mean rank of condition scores Period with lowest	second highest	Period with highest
Harem stallion	**P=0.018***	Feb-Mar 1985	Sep-Oct 1984, NS	**Sep-Oct 1986***
Harem mare	**P<0.001***	May-Jul 1985	Feb-Mar 1985, NS	**Sep-Oct 1986***
Bachelor adult	P=0.053, NS	May-Jul 1985	Oct-Nov 1985, NS	Sep-Oct 1986, NS
Conclusion from AOV: The condition of harem stallions and mares changed during the study. The condition of bachelors did not change significantly.		**Conclusion from multiple comparison:** Harem mares and stallions were in better condition in the period from September to October 1986 than at any other time during the study.		
* statistically significant difference at the 5% level NS not significant				

d) Condition and pregnancy

Post mortem examination of 195 horses shot during a control exercise revealed that 32% of the population were females more than two years old (assumed mature enough for breeding). Of these adult females 55% were pregnant. The pregnancy rate for mares in good condition was 83% and for those in poor condition only 9%. The difference between body condition scores for pregnant and open (not pregnant) females was statistically significant (Mann-Whitney U test P=0.0001) indicating that mares must be either in relatively good condition to conceive or maintain a pregnancy or improve in condition during pregnancy. Lactation does not appear to inhibit pregnancy but the cost

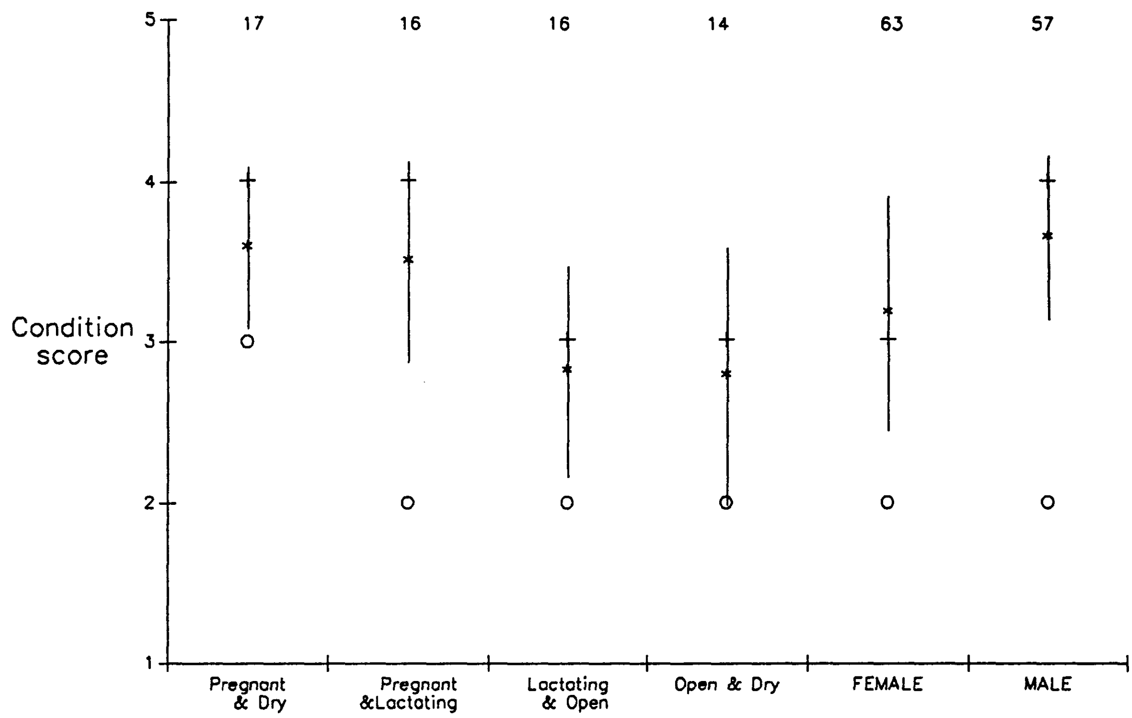

Figure 7.6: Condition of adult horses (age>=3 years) examined post mortem in May 1986. Vertical lines, *, +, and o represent the standard deviation, mean, median and minimum scores respectively.

of lactation may cause loss of body condition which in turn reduces the probability of pregnancy (Figure 7.6). At the time of post mortem examination the reproductive rate for the population was 0.18 female births per female per year (i.e. females of all age classes including foals and sub-adults). The results indicate that if all female adults were in good condition there could be 0.27 female births per female per year. This birth rate could drop to 0.03 if all female adults were in poor condition.

e) Changes in pasture and mares with foals

The number of juveniles recorded per 100 harem adults (male and female) decreased as the biomass of annual pasture decreased ($r=0.90$, $P<0.001$). Table 7.5 shows a decrease in the proportion of mares recorded with foals seen along ground based transects from 79% to 50% from October 1985 to October 1986. This decrease was probably due not only to reduced pregnancy or increased foal mortality but also to a delayed season of birth. These data from transects are consistent with those from post mortem examination. Since 32% of the population are female adults capable of breeding and 79% of those were accompanied by foals in October 1985 then there were at least 0.25 female births per female (cf. 0.27 from post mortem sample). Similarly in 1986 50% of mares were accompanied by foals which converts to at least 0.16 female births per female (cf. 0.18 from post mortem sample) (Table 7.5).

Table 7.5: Percentage of mares with foals seen along ground based transects on the Hale Plain for groups where all adults were classified by age and sex.

	October 1984	October 1985	October 1986
Percent with foals	80%	79%	50%
Estimated female births/female (all ages)	0.25	0.25	0.16
Number of mares	10	29	26

f) Age structure

The mean age according to tooth-wear and eruption, for 122 horses trapped at watering points (August 1985) on The Garden station was 5.1±3.9 (SD) years. Nine months later on a property neighbouring The Garden station the mean age was 5.0±4.1 (SD) years for horses autopsied during a control exercise. The non-parametric Rank Sum Test produced a non-significant result indicating that the age distributions did not differ between years. Table 7.6 shows that the distribution of 2-year age classes do not differ significantly between years.

Figure 7.7 shows the age distribution to be irregular using 1-year age classes. This irregularity could be due either to age determination bias or to actual fluctuation in birth and mortality rate or to both. Section 7.3.6 provides some evidence to suggest that bias in age determination may not be the major factor. The small proportion of 4 and 5-year-olds relative to 6 and 7-year olds can be explained if there was a low birth rate 4 to 5

Table 7.6: Age distribution (2 year classes) determined post mortem for horses trapped 20 km north west of the Hale Plain (August 1985) and shot 35 km south east of the Hale Plain (May 1986).

Age class (years)	August 1985		May 1986	
	Number	%	Number	%
0<age≤ 2	49	42	76	39
2<age≤ 4	17	15	25	13
4<age≤ 6	19	16	26	13
6<age≤ 8	15	13	24	12
8<age≤10	9	8	23	12
10<age≤12	4	3	13	7
12<age≤14	4	3	3	2
14<age≤16	5	4	4	2
age>16	0	0	1	1
TOTAL	122		195	

Comparison of frequency distribution of age-classes showed no difference between the samples (Chi-squared=4.9, P=0.55, df=6) when grouped into 2-year age classes. Horses older than 12 years were grouped into a single class for statistical analysis.

years before the study and/or high mortality of 0 to 5-year-olds during the previous 5 years. Low rainfall was recorded for 1980 and 1981 which may have resulted in low birth rate in 1981 and 1982 (Figure 1.3). Low rainfall was also recorded in 1985 perhaps resulting in high mortality of 3 or 4-year-olds (section 7.3.5.b) supports this). Both these factors could well have contributed to the low frequency of 4 and 5-year-olds. Two techniques were used to reduce the irregularity of age distribution before determination of survival rates. Horses were grouped into 2-year age classes before using the Chapman-Robson method and 1-year age distributions were smoothed using log-polynomial curves to produce life tables. Major stages of tooth-wear and eruption are relatively easy to determine with very little chance for mistakes and were useful for comparing the 1985 and 1986 post mortem samples (Figure 7.8).

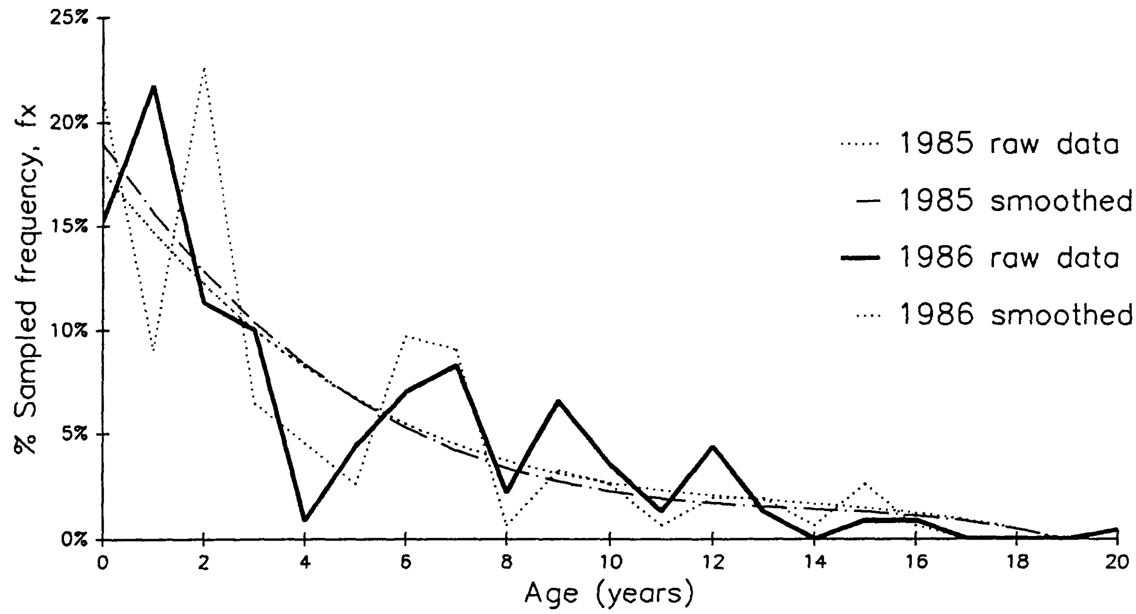

Figure 7.7: One year age class distribution determined for horses examined post mortem in August 1985 and May 1986. Age was determined by tooth-wear and eruption technique. Raw data smoothed with a log-polynomial curve.

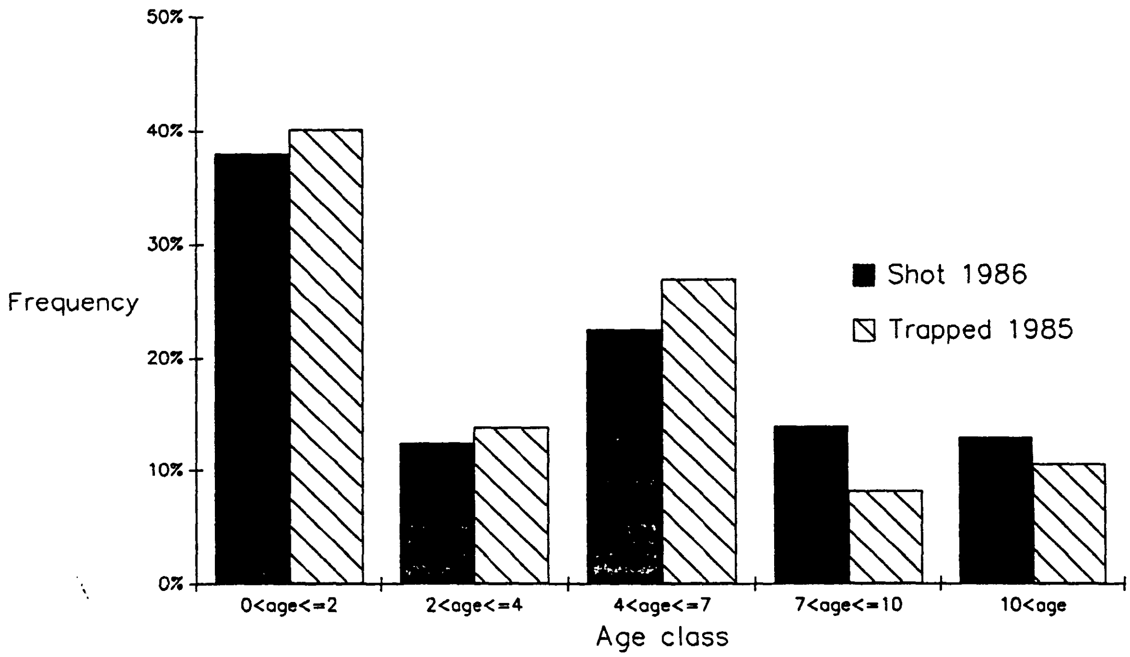

Figure 7.8: Comparison of the age distributions for August 1985 and May 1986 post mortem samples using major stages of tooth-wear and eruption (Chi-squared=3.37, df=4, P=0.50, NS).

Figure 7.9: Sex ratio for age classes determined using major stages of tooth-wear and eruption to age horses examined post mortem, May 1986. The number of horses in each age and sex class is shown at the end of each bar.

g) Sex ratio

There was a significant difference ($\chi^2=10.4$, df=4, $P<0.05$) (Figure 7.9) between the age structures of males and females in the 1986 sample when age classes were determined using major stages of tooth-wear and eruption (see chapter 2 for age determination method). Female foals (less than 2 years old) appear to suffer greater mortality rates than male foals. Then between 2 and 4 years male mortality appears higher than female. For horses older than 4 years females appear to suffer the higher mortality rate. These conclusions assume that the sex ratio at birth has been consistently 1:1. Support for this assumption comes from the 1986 (17:16) sample of foetuses.

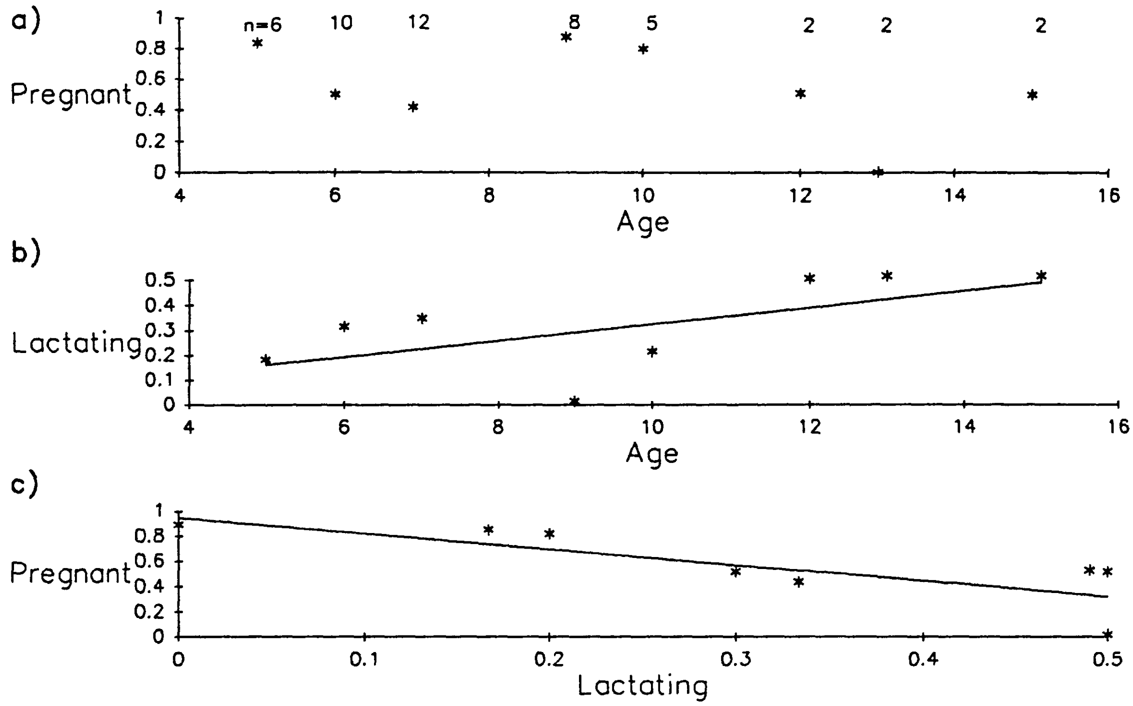

Figure 7.10: Regressions of a) pregnant mares against age (r=-0.44, NS), b) lactating mares against age (r=0.64, P<0.10) and c) proportion lactating against proportion pregnant (r=-0.80, P<0.01) in each 1-year class (May 1986).

h) Birth rate and age

No females less than or equal to two years old were found to be pregnant. Excluding the youngest class (<=2 years) from the analysis the difference in age structure of pregnant and non-pregnant females was not statistically significant (χ^2=6.5, df=3, P<0.10). To see how age, pregnancy and lactation interact, age classes older than 4 years, where n>1, were selected for regression analysis. Figure 7.10a shows the proportion of mares that were pregnant did not change significantly with age. However, there was an indication that older mares were more likely to be lactating than younger mares (Figure 7.10b). A high proportion of lactating mares in age classes tended to be associated with a low proportion of pregnant mares in that age class (Figure 7.10c). Figure 7.10 indicates that older mares are more successful in rearing foals than younger mares because although older mares were more likely to be lactating, they were not more likely to be pregnant. This requires further analysis for confirmation. All factors (older vs younger, preg. vs lact. vs dry) should be compared simultaneously and the effect of historical patterns must be identified. As mentioned in section 7.3.3.d) lactation does not appear to inhibit pregnancy but low body condition resulting from the cost of lactation may inhibit pregnancy.

7.3.4 Fecundity

Age specific female fecundity estimates based on post mortem examination of horses shot in May 1986 are presented in Table 7.7. The estimated proportion of female births per female per year was 0.27 in 1985 and 0.18 in 1986 (Table 7.8). Assuming the sex ratio was 1:1 and the age distribution of the whole population was the same as the sample then I expect there to have been 0.27 and 0.18 births per horse (any sex and age) in 1985 and 1986 respectively. I believe these to be fair assumptions since age distribution and sex ratio was consistent for horses shot and trapped in two different places and times. The possibility of abortion cannot be ruled out. However, this most commonly occurs in the first 6 months of pregnancy (Berger, 1986). Most foetuses examined had passed this critical age.

7.3.5 Survival rate

a) Shot and trapped samples

Two approaches were used to determine survival rates (Table 7.9) of 79 and 80% per year. Methods for estimating the survival rates require the assumption that there is a constant survival rate throughout all age classes. The irregular age distribution makes it difficult to test this assumption for 1-year age classes. However, the Chapman-Robson method using 2-year age classes produced a survival rate for 2 year periods of 64±5% (95%CI) and 65±4% for 1985 and 1986 samples respectively. The annual survival rates (80 and 81%) were calculated by taking the square roots of the 2-year survival rate. Using the conventional life table approach (Caughley, 1977) annual survival rates of 79% were estimated using both years' samples (Table 7.9).

Table 7.7: Fecundity table using proportion of pregnant or lactating females examined post mortem in May 1986. B_x represents the number of foals f_x should produce in 2 years.

Age (years) x	Sample size f_x	Pregnant or lactating B_x	Female births per female per year m_x $(B_x/4f_x)$
0 to 2	30	1	0.01
3 to 4	13	7	0.14
5 to 6	16	20	0.32
7 to 8	13	11	0.21
9 to 10	13	19	0.37
>10	7	7	0.25
Total	92	65	0.18

Table 7.8: Female births per female (all ages) per year based on the presence or absence of foetuses in horses examined post mortem (Aug. 1985, May 1986 and Aug. 1990). Horses not shot in the field were slaughtered at abattoirs.

Year	Source of carcasses	♀ births/♀/year	n
1985 August	Trapped at water, north west part of The Garden	0.27	39
1986 May	Shot from helicopter on station neighbouring The Garden	0.18	92
1990 August	Mustered by helicopter in Porter's Well area	0.25	62

Table 7.9: Survival rate calculated using a) the Chapman-Robson method, 2-year age classes, and b) life tables. Horses examined post mortem in August 1985 and May 1986.

a) Chapman-Robson method with horses grouped into 2-year age classes (>12-year-olds were pooled).

Year	Sampling method	Annual survival	2-year survival	95% CI	z^2	Chi^2
1985	Trapped	0.80	0.64	0.05	1.4 NS	11.8 NS
1986	Shot	0.81	0.65	0.04	2.0 NS	25.8 *P<0.001

* z^2 and Chi^2 are used to test the validity of the assumption of constant survival throughout all age classes. The data for 1986 does not fit a geometric distribution (i.e. there is not a constant survival throughout all age classes).

b) Life table method horses grouped into 1 year age classes. Frequency smoothed using log-polynomial

Year	Sampling method	Annual survival	
1985	Trapped	0.79	No estimate of precision or test for constant survival through years
1986	Shot	0.79	

b) Collected skulls

There were 18 skulls collected on The Garden station; 4 were females and 13 males (1 unknown sex). At least 6 of The Garden station skulls may have been from horses shot for pet meat. The causes of death of the other horses were not known. Four skulls had lost their teeth and could not be aged. Nine out of the 14 aged skulls were more than 2 years old and less than or equal to 4 years old at death. Only 5 skulls were older than 4 years and 3 of these were older than 10. The high proportion of 3 and 4 year olds may help explain the lack of 4 and 5 year olds found in both post mortem samples and therefore the irregular age distribution (see section 7.3.3.f)). The lowest mortality rate on The Garden station appeared to have occurred for horses less than or equal to 2 years and for horses from 4 to 10 years but this sample is small and the results inconclusive.

Figure 7.11 shows the age structure of horses that died near Farrer Spring on Tempe Downs Station. Most of these horses apparently died of starvation during the drought (1984-1986). The age distribution does not appear to be very different to that of the trapped and shot horses. However, grouping horses into classes determined by major stages of tooth wear and eruption, and comparing the 1986 shot sample with those that died of drought shows horses less than 2 years old to have died in greater numbers than expected and those >4 and <=7 to have survived the drought better than expected (χ^2=11.97, df=4, P=0.018) (Figure 7.12). Of course, these conclusions assume the age distribution of the two living populations to be the same before death. I have no data to confirm this assumption.

7.3.6 Grinding to a halt

I considered using domestic horses living near the study area to check the accuracy of the technique for age determination. However, most of these stock horses were older than 10 years and their exact age was not known. Figure 7.13 shows that age estimated by tooth wear and eruption has a highly significant linear correlation with the length (i.e. height from tip of root to crown) of the first premolar. This relationship provides a simple means to check accuracy of the age determination technique. I assessed the tooth wear and eruption prior to measurement (with callipers to nearest mm) of length of the premolar so I was not influenced by the measurement (Figure 7.13).

Figure 7.13 also indicates that the first premolar of feral horses will wear out before a horse reaches 25 years of age. Feral horses in central Australia would therefore probably experience increased difficulty grinding food after 20 years of age. They are unlikely to live longer than 30 years.

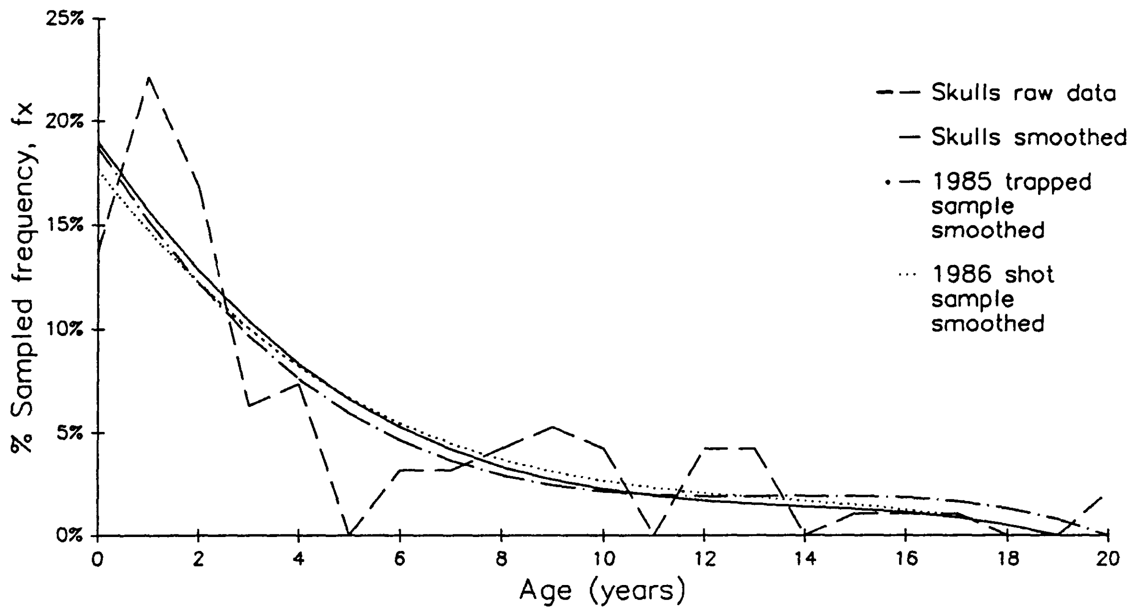

Figure 7.11 The log-polynomial curve fitted to the age distribution of horses that died during drought at Farrer Spring on Tempe Downs. Fitted log-polynomial curve is compared to curves fitted to shot and trapped samples.

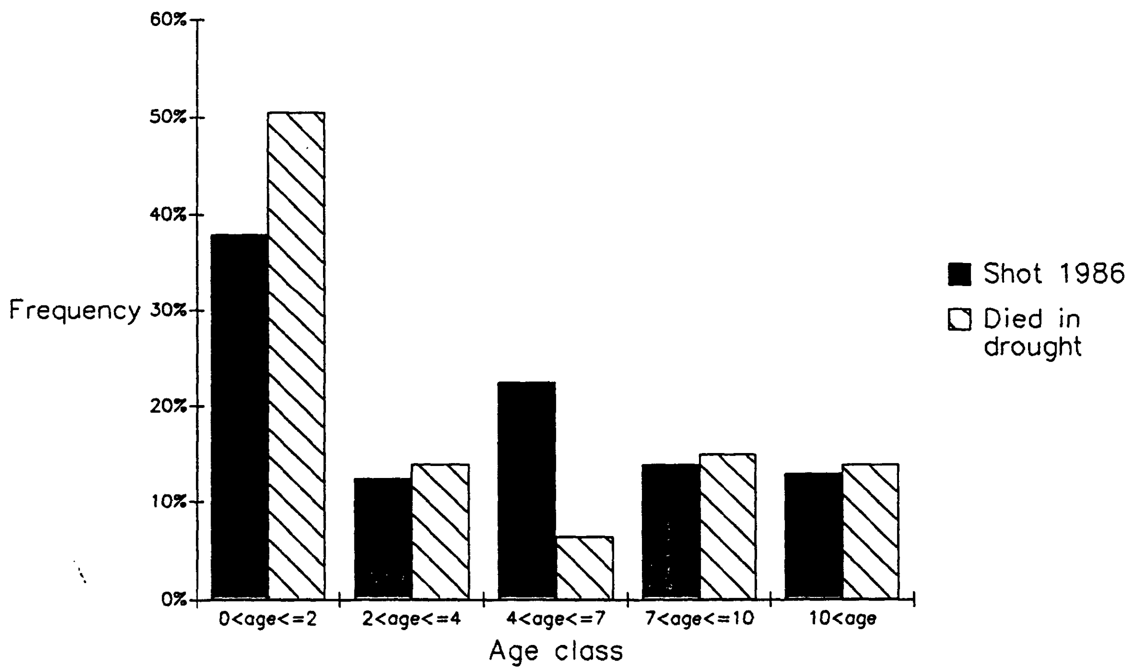

Figure 7.12: Comparison of age distribution for horses shot during a control exercise near The Garden station (May 1986) and those that died during drought at Farrer Spring (1985-86).

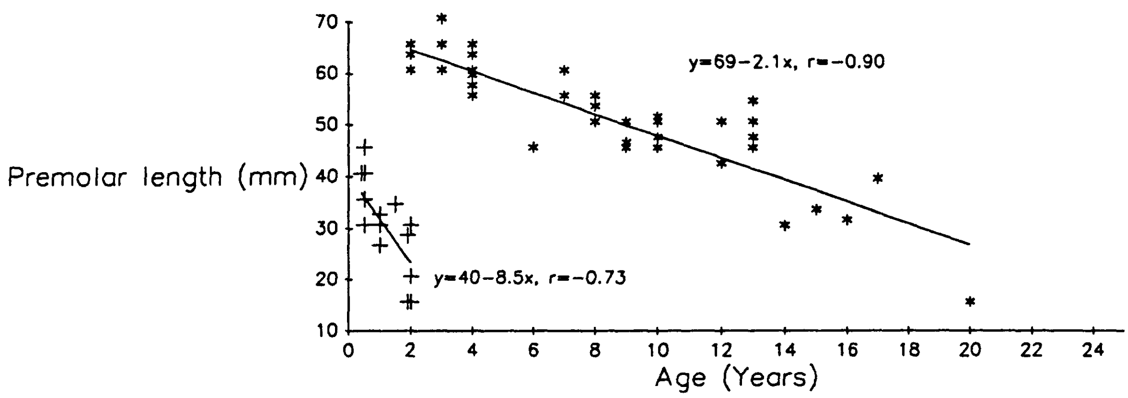

Figure 7.13: Regression of first premolar length (height from tip of root to crown, adult * and juvenile +) and age for skulls collected 250 km south west of Alice Springs.

7.3.7 Harvest

On The Garden a total of 1202 horses were trapped in yards as they came to drink during the 2 year period from March 1986 to March 1988. Figure 7.14 shows that most of these horses were trapped in 1987. All trapped horses were removed from the population. The similarity between the age distribution of horses shot during a control exercise and those trapped as they come to drink indicates that no age class is trapped preferentially to any other (Figure 7.8). Trapping therefore does not appear to alter the age distribution of the remaining population.

7.3.8 Verification of population change model: Aerial survey data

Table 5.12 shows the population of feral horses on The Garden station to have dropped 31% from 2497 to 1732 in 2 years. The exponential rate of population change r was -0.18 per year. This decrease may have resulted from migration out of the survey area or natural mortality and reduced reproductive rates due to dry conditions. However, by far the largest influence was trapping which accounted for the removal of 1202 horses during the 2-year period.

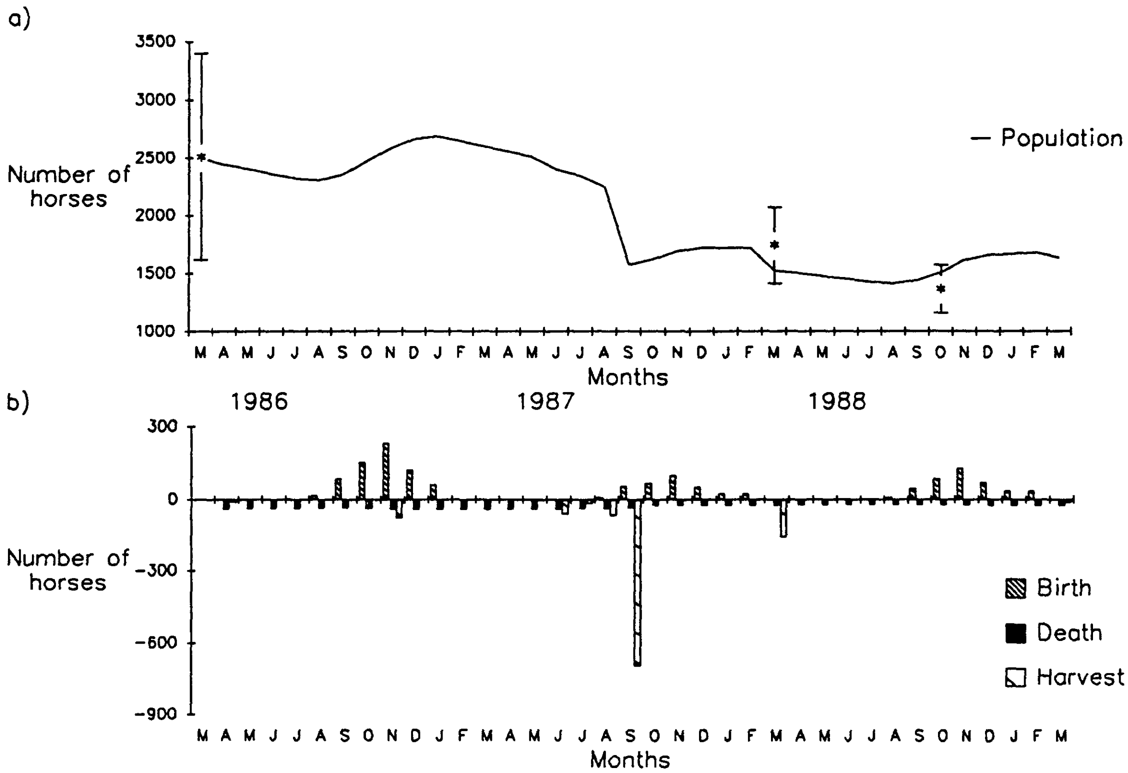

Figure 7.14: a) Model of change in The Garden feral horse population incorporating b) monthly birth, death and harvest rates (not age specific). Vertical lines (95% CL) and mean (*) population sizes from aerial survey are shown.

Figure 7.14 shows the modelled change in population determined using birth, death and harvest rates. Beginning with the 1986 aerial survey estimate of The Garden feral horse population each month the number of removals (death or harvest) and additions to the population were used to calculate a new population size. A natural mortality rate of 20% per year was apportioned to determine the proportion of the population that died of natural causes per month. This number was then subtracted from the previous month's population size to give the new month's estimated population after natural mortality. For years following good rainfall and pasture growth (1987 and 1988) the annual foaling rate of 25% was assigned and 18% was applied to 1986 which followed a relatively dry year. The 1986 and 1988 rates were determined from post mortem examination of horses while that for 1987 was assumed to match the best determined from post mortem because the rainfall for winter 1986 produced abundant green pasture and improved the condition of all horses. So for a good year I assigned 25% birth rate per year and for a bad year I assigned 18%. The season of birth estimated by measurement of foetus length (both samples combined) provided the number of foals produced for each month of the year. Thus the proportion of the annual birth rate was assigned to months based on the expected proportion of foals to be born in that month. For example, if 2000 was the population size at the end of September, 37 (1.84%x2000 i.e. the 12th root of the annual mortality rate of 20%) would die of natural causes during October, leaving 1963 horses. If 23% of all foals born in that year were predicted to be born in October, 23%x18%x1963 provided an estimate of the number of foals born in October (81 foals) which was added to the post-mortality population estimate to give an estimate of 2044 horses at the end of October.

The model is admittedly rough and does not account for changes in age-specific fecundity or survival rates. However, these are difficult to determine and may vary unexpectedly depending on conditions. If age-specific rates were used I believe there is an increased chance of producing a misleading model; the model may only appear more precise than my simplified version. The modelled changes in population corresponded well with population estimates from aerial survey. This indicates that the important population parameters have been included and reasonable estimates determined.

7.4 Discussion

7.4.1 Population parameters

Figure 7.15 shows the parameters potentially important in central Australia for those who wish to model feral horse population changes. In this study birth, death and harvest appear sufficient to predict population changes (Section 7.3.8). Measurement of immigration and emigration may not be necessary. Dobbie and Berman (1990) found feral horses to have high fidelity to their home range and therefore I believe immigration and emigration to have insignificant influence on population sizes at least within a 3 year time frame. However, under different circumstances immigration and emigration may

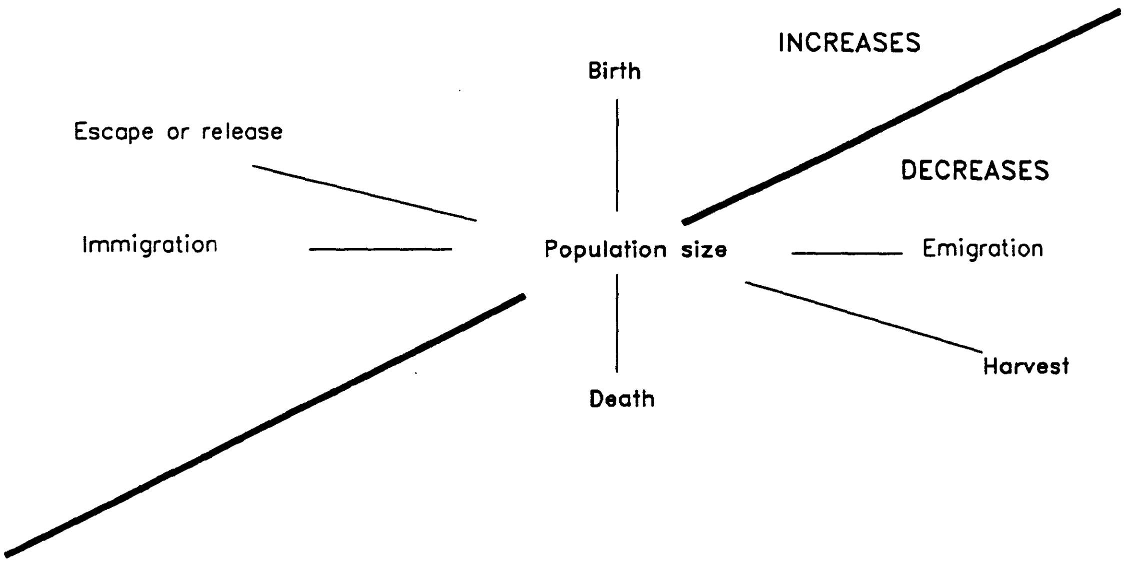

Figure 7.15: Population parameters for modelling feral horse populations. The parameters in bold were found to be important in this study.

become more important. For example, if different management or seasonal conditions cause neighbouring stations to have very different densities of horses I would expect horses to move from the more dense to the less dense. However, under most conditions immigration and emigration appear insignificant compared to birth, death and harvest.

7.4.2 Birth and death

In central Australia the season of birth and age-specific pregnancy rates are best determined by post mortem examination of horses either shot where they graze or trapped in yards as they come to drink. However, such data are not as readily available as counts of living stallions, mares, sub-adults, juveniles and new born foals along ground based transects, which, although somewhat subjective, is a useful method for determining birth rates, sex ratios and general age structure, as long as care is taken to sample the population adequately. For production of a population model, using 10 to 20% birth rate for poor years and 25 to 30% for good years may suffice where data are not available for a particular area. For most years an overall 80% survival appears suitable. However, this may vary depending on population density, rainfall and pasture conditions. Survival rates up to 95% have been reported for feral horses in North America (Wolfe, 1986) and may be appropriate for good years or when populations are well below carrying capacity in central Australia. These estimated birth and survival rates can be used in the model that I have described assuming the sex ratio of the population is 1 to 1 and the age structure is similar to that found for horses in my study. These assumptions appear valid for feral horses in central Australia but can be checked simply by transect counts and the model adjusted accordingly. The model I have presented is simple, appears accurate and should be useful for managers responsible for control of feral horses.

7.4.3 Harvest, escape or release

Although few horses escape or are released into the feral populations these days harvest or control are significant parameters influencing feral horse populations in central Australia. Humans should, I believe, be considered as feral horse predators. Further, the intensity with which we prey on feral horses is density dependent. My study was initiated because humans perceived the densities of horses to be too high. In the early 1970s the density was not high enough for horses to be regarded as a significant pest (Letts et al., 1979) so other feral animals were placed higher on the list of priority for action. It is possible that the good rainfall years of the 1970s resulted in the Northern Territory feral horse population increasing by a factor of 4. Such an increase could be easily achieved with a birth rate of 25% and a mortality rate of 5% which are possible based on my data and those presented by Wolfe (1986). We humans have responded to the high densities of horses by establishing an Abattoir at Tennant Creek and by conducting research that ultimately improved methods of harvest (Dobbie & Berman 1990; Berman, 1991; Chapter 9). Dry conditions, lack of pasture and free water, and improved management have combined to reduce the feral horse population by a factor of 70-80% in central Australia (Low, 1990). Now the numbers are down humans (the predator) may turn to other prey. Research funds will dry up and horses will in time, given the right conditions, return to previously high levels before we (the predator) respond once more.

The relationship between humans and horses is not however, simply a predator-prey relationship. Horses are thought to compete with our cattle for food and water (Chapter 4) and they are also thought to threaten the environment that we live in (Chapter 8); and therefore humans may be thought of as not only predators of horses but as competitors. This relationship only serves to heighten our awareness of the density of horses. It is an additional reason for humans to respond to horses in a density-dependent fashion. The next Chapter looks at the impact feral horses are having on the central Australian environment.

7.5 Conclusions

Values for birth rate, mortality and harvesting derived during the study were applied to an initial population size, to model the performance of the population from 1986 to 1989. The resulting "modelled" population sizes compared well with those estimated from aerial surveys, suggesting that the three variables used efficiently predicted population performance. In the conditions of the study immigration and emigration seem not to have been important.

CHAPTER 8
ENVIRONMENTAL IMPACT

8.1 Introduction

The study of foraging behaviour of horses and cattle on the Hale Plain (Chapters 3, 4 and 5) identified distance from drinking water to be an important factor determining the distribution of stock. Horses are more mobile than cattle and used areas more distant from water (Chapter 5). Horses more readily used hills than did cattle. However, both horses and cattle grazed closer to water soon after rain had induced plant growth; and as grass was removed stock responded by either feeding less selectively when close to water (mainly cattle) or by moving further from water (mainly horses) but continuing to graze selectively (see Chapters 4 and 5 for details on diet and habitat use). The cumulative effect of both horses and cattle is that pastures close to water, particularly those dominated by palatable grasses, come under the greatest grazing pressure and therefore more often have less biomass (Chapter 4), and, we suspect (G. Bastin, pers. comm.), less stable botanical composition than pastures more distant from water. From the results of Chapters 3 to 5, I hypothesise that the impact of horses and cattle on soil, vegetation and wildlife will decrease as distance from water increases.

Many people believe that grazing ungulates have had a major impact on the soils of arid Australia during the last 100 years (Woods, 1983; Pickup and Chewings, 1988). Striking examples of soil erosion exist in some areas of central Australia and are often attributed to overgrazing by horses and cattle. Nevertheless, it is difficult to prove that a significant amount of erosion is caused by the activities of stock because erosion also takes place without stock. There are obvious examples of erosion induced by the activities of stock. Hard hooves detach soil particles making them available for transport by wind or water. Removal of ground cover exposes the soil to the action of wind and rain allowing increased runoff and therefore more rapid removal of soil. No-one knows just how much trampling or grazing is required to accelerate erosion above the natural rate in central Australia. Nor do we know how this threshold varies between soil types. However, for this study I postulate that heavily grazed areas are more likely to have experienced accelerated erosion than areas of similar erodibility which are less frequently used by stock.

There is indication that domestic and feral animals have helped reduce many of the medium-sized Australian mammals to mere relics of their former population. Seven species of mammal have probably become extinct in the last 50 years and 12 species are either endangered or vulnerable (Wilson et al., 1984). Foxes, cats, rabbits, donkeys, cattle, camels and horses together exert a strong influence on the native species and habitats of central Australia. Eradication of all introduced animals is impossible so we must manage their populations to control their impact. The CCNT has been breeding bilby (*Macrotis lagotis*) and mala (*Lagorchestes hirsutus*), two of the endangered marsupials, in captivity and are currently reintroducing them to their natural habitat. The success of such projects requires control of the impact of introduced animals by management of their populations. Selection of appropriate management strategies must be based on a sound knowledge of the impact of introduced (domestic and feral) animals.

There has been considerable research done on the environmental impact of cattle, particularly in relation to deterioration of arid zone pasture. Hindmarsh (1980) stated that the thin soils and sparse plant cover of Australia's arid zone appear to have changed greatly since European settlers introduced stock. There is evidence that grazing has modified the floristic composition of arid Australian vegetation perhaps "not because stock are particularly selective feeders - they are far less selective than the native macropods (Chippendale, 1962, 1968) but because some plant species are less tolerant of grazing than others" (Buckley, 1985). Brown (1981) noted that wiregrasses (*Aristida* spp.) are increasing in abundance in Queensland's arid rangelands at the expense of the more palatable species. It is commonly assumed that similar changes have occurred in central Australia and that these changes reduce the value of pasture to cattle.

The Northern Territory Department of Primary Industries and Fisheries (formerly the Department of Primary Production) in collaboration with CSIRO have been monitoring condition of rangelands in central Australia for over a decade (Foran, 1980) by fixed photograph points, estimation of pasture species composition, amount of woody weeds, and type and degree of erosion at fixed sites on stations. These studies indicate that more heavily grazed areas tend to have less stable pasture species composition, but the major driving force is season. The unpredictable timing and amount of rainfall in central Australia cause fluctuations that tend to hide grazing-induced changes in pasture species composition. In the short term it is difficult to quantify grazing-induced changes, but the long-term trend appears to be towards a less productive pasture, more often dominated by the poorest pasture species. Palatable perennial grasses appear to be the first to disappear from overgrazed areas (G. Bastin, pers. comm.).

Other studies illustrate the difficulties faced by those who attempt to quantify grazing-induced changes in the botanical composition of central Australian pasture. For example, the impact of cattle and rabbits on vegetation has been assessed by comparing vegetation inside and outside fenced areas (exclosures) which excluded cattle and/or rabbits. Neither exclosure nor distance from water produced any consistent significant trend for any plant attribute measured over the first 7 years of data collection. However, the different timing and amount of rainfall produced very large fluctuations (Foran et al., 1982). In a further exclosure study Foran (1986) concluded that seasonal conditions and soil factors accounted for most of the changes in species composition of pasture when rainfall conditions were moderate to good.

Feral horses certainly have the potential to reduce the productivity of the central Australian cattle industry by eating forage valuable for cattle production (see Chapter 4). However, this is not justification enough to convince animal welfare groups that harvest/cull programmes are necessary. To decide on the most appropriate management strategy for feral horses we need to know more about their environmental impact. The work reported here aimed to determine if horses are having a measurable impact on the environment, and to distinguish between the impacts of horses and cattle. Environmental impact of feral horses was defined as any change to the environment caused directly or indirectly by feral horses.

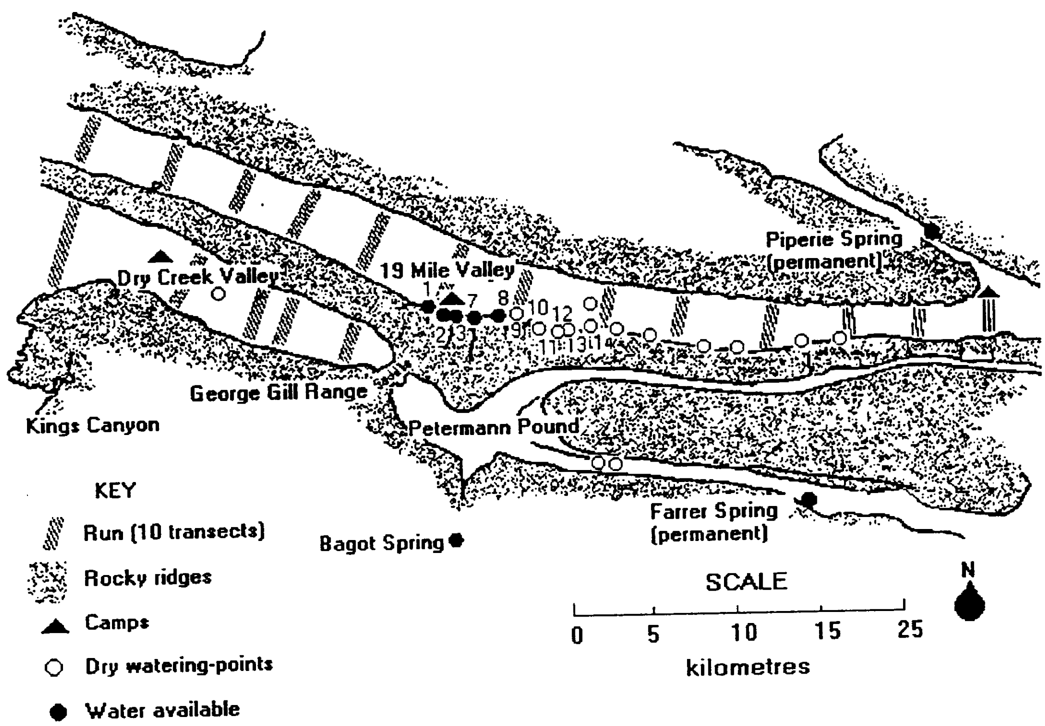

Figure 8.1: Map of the Kings Canyon study area showing where groups of 10 parallel transects (Runs) to count animal sign, vegetation and soil characteristics were placed. Identity numbers of dry and wet water-holes are shown.

8.2 Methods

The study area and data collection methods are described in detail in Chapter 2. Most data for this study were collected during 6 weeks (May/June 1986) by Operation Raleigh venturers, Australian Army personnel, and volunteer biologists (see Chapter 2 for details) and the results were previously presented in a report to the CCNT (Berman & Jarman, 1988). In the Kings Canyon study area 250 km south west of Alice Springs we surveyed Nineteen Mile valley (used by both horses and cattle) and Dry Creek valley (grazed by horses alone) (Figure 8.1). The valleys (from 3 to 5 km wide) were surveyed along transects from side to side recording signs, vegetation and soil characteristics (Chapter 2).

Plate 8: Photo (a) shows Athol's ears listening to a feral horse in the Dry Creek valley. The Kings Canyon area was thoroughly inspected before selection for the study of environmental impact. The valley systems in the Kings Canyon area are long and narrow (3 to 5 km wide) with steep sides as shown in photo (b) of the Petermann valley and (c) of the Dry Creek valley. Establishment and assessment of sites (c) in the Dry Creek valley by Alan Anderson and myself indicated the need for a large number of sample sites. This was achieved by obtaining help from Operation Raleigh (d). Operation Raleigh expedition members are shown spaced in pairs 50 m apart searching circular sample areas for animal sign in the Dry Creek valley (d). Variables recorded included pads (e & f), horse hoof-prints (e), horse dung piles (f), scald and gully erosion (g & h).

8.3 Results

8.3.1 Water-holes

a) Distribution and permanency

i) Nineteen Mile valley

At the eastern end of Nineteen Mile valley Expedition members located permanent springs (Piperie Spring) with clear water and signs of heavy stock use (Figure 8.1). Carcasses of both horses and cattle which apparently died of starvation were found there indicating the importance of these springs to stock during drought. About 20 to 40 kilometres west of the springs a number of semi-permanent water-holes were found (Figure 8.1). Of 14 water-holes described by P.J. Jarman (Berman & Jarman, 1988) in Nineteen Mile valley only water-holes 1,3,7 and 8 had water for stock (Figure 8.1). Water-hole 1 had many horse carcasses; 3 had water at the bottom of a steep, smooth rock, 7 was a mud-hole where horses were seen sucking mud; 8 was a pool up a long, narrow gorge. Other water-holes inaccessible for stock usually had clear water and signs of euro, rock wallabies and dingoes. Three of the largest water-holes can hold water for up to 11 months after rain according to Brian Bowman (see Chapter 2). For up to a month or two after rain ephemeral water-holes exist right along Nineteen Mile valley. Many of these were located during the 1988 survey by helicopter soon after rain.

ii) Dry Creek/Petermann valleys

We confirmed that Dry Creek valley had no permanent watering points. In June 1986 horses were entering the valley from the east, over the saddle from Petermann Pound, and appeared to be watering at Farrer Spring (Figure 8.1) some 50 km from where we saw them. Horse carcasses were found at Farrer Spring. There are ephemeral water-holes in Dry Creek valley but none contained water in June 1986 when Operation Raleigh took place. The largest of these ephemeral water-holes (Figure 8.1) may hold water for periods up to 6 months but the rest are probably dry within a month or two of rainfall.

b) Importance of particular watering points

i) Nineteen Mile valley

Expedition members counted 54 horse carcasses near water-hole number 1 in Nineteen Mile Valley (Figure 8.1) indicating its importance as a watering point. Eleven were in the water-hole, 25 within 100 m and 18 scattered within 2 km of the water-hole. A large number of carcasses (>20) were also seen near Piperie Spring but no accurate count was made. These two watering points appear to be the most important to stock in Nineteen Mile valley because few carcasses were found elsewhere. Horses may have died of thirst or starvation near water-hole number 1 but at Piperie Spring starvation is the most likely cause of death because these springs are permanent supplies of water (Figure 8.1).

ii) Dry Creek/Petermann valleys

Seventy three horse carcasses were found by Mark Fosdick in the vicinity of Farrer Spring (July 1986) indicating the importance of this watering point to horses. Horses probably died of starvation not lack of water. Farrer Spring is a permanent supply of water for stock.

8.3.2 Distance from drinking water

a) Within 5.5 km of a water-hole

To determine relationships between variables in areas relatively close to water (less than 5.5 km) the data collected during a single run (group of 10 parallel transects) across Nineteen Mile valley were analysed. There was a total of 222 (n) circular sample areas searched for animal sign, vegetation and soil characteristics along the transects. The circular sample areas (15 m radius) were placed 200 m apart measured by stepping. The transects began close to semi-permanent water-hole number 1 (Figure 8.1) and finishing on the northern side of the valley 5.5 km away from any water.

i) Distribution of horse and cattle signs

In 99% of the 222 circular sample areas horse signs (dung and/or tracks) were found and for 44% cattle signs were recorded. Only 1% of sample areas had no sign of horse or cattle having been there. The run (group of 10 transects) beginning at water-hole number 1 was split into 400 m lengths and means (n=20 sample areas) for the 13 rectangular sections (450 m x 400 m) were calculated. The mean number of horse defecations, the mean number of cattle defecations (Figure 8.2) and the mean number of pads (stock trails) created by both horses and cattle were (Figure 8.3) all negatively correlated with distance from the semi-permanent water-hole. These results indicate that distance from semi-permanent water influences the distribution of horse and cattle signs in areas less than 5.5 km from water.

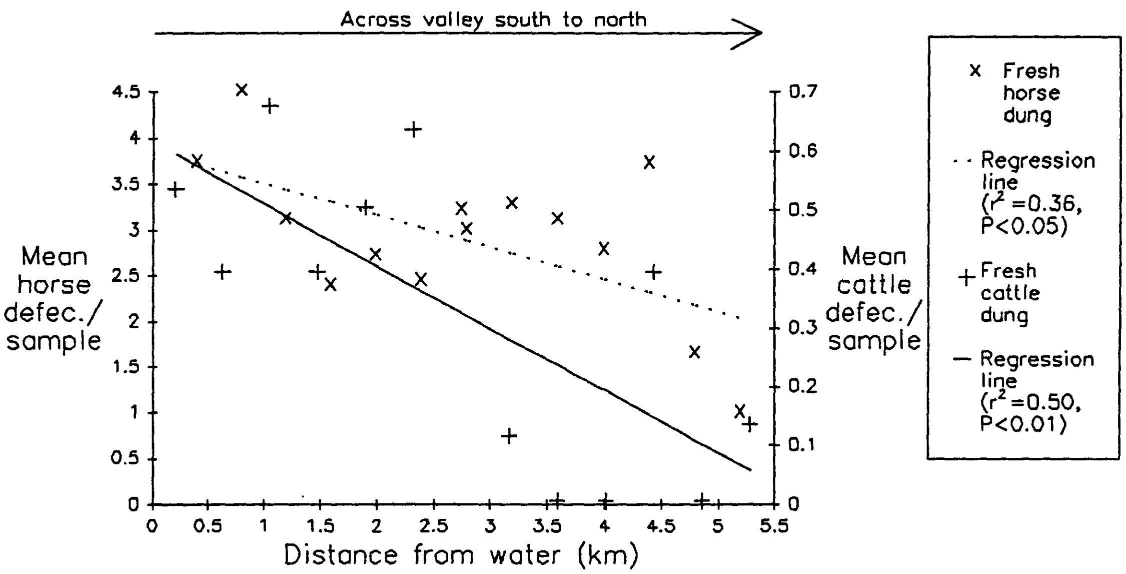

Figure 8.2: Mean number of horse defecations and cattle defecations per circular sample area plotted against distance from water-hole number 1, 40 km from permanent water in 19 Mile valley.

ii) Distribution of herb cover

Figure 8.4 shows that mean percent herb cover was positively correlated with distance from the semi-permanent water-hole. Stock appear to have reduced the herb cover in areas they used most intensively, close to water.

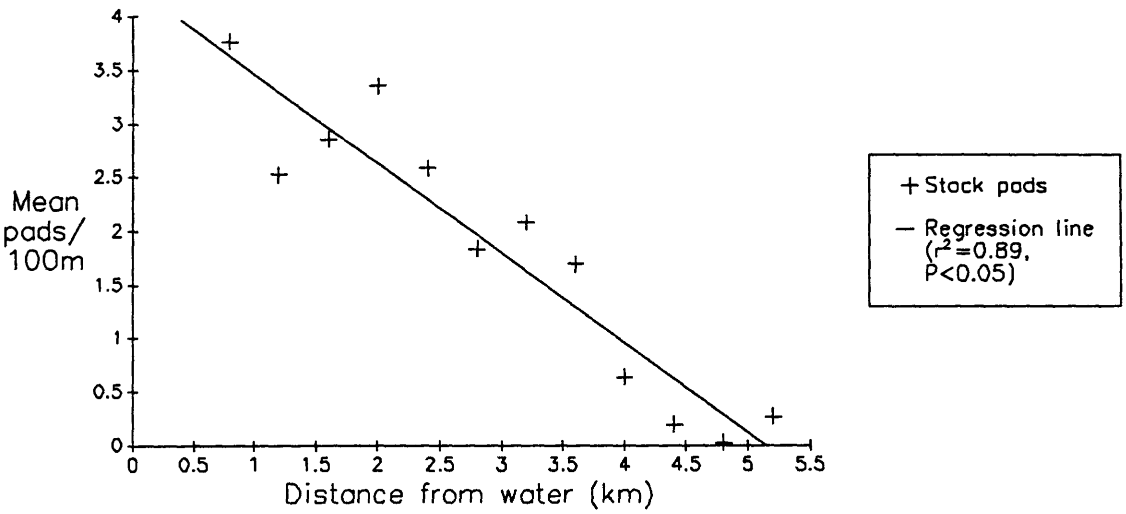

Figure 8.3: Stock pads (trails) created by both horses and cattle walking repeatedly over the same path to and from a watering point plotted against distance from water-hole number 1 (19 Mile valley).

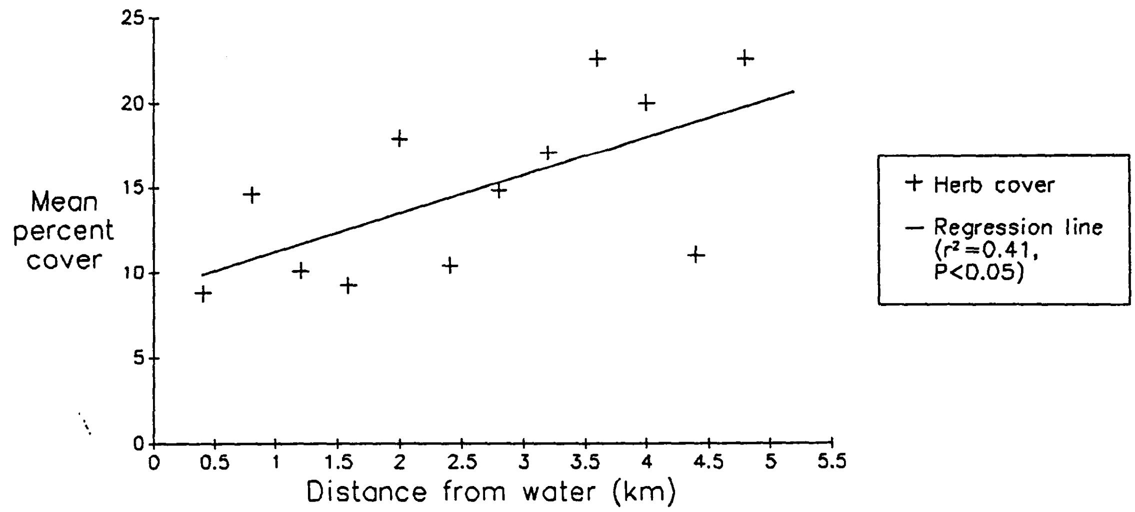

Figure 8.4: Mean percent herb cover plotted against distance from water-hole number 1 (19 Mile valley). Means were calculated for 400 m x 450 m sections of the group of 10 transects (n=20 sample areas).

iii) Distribution of erosion and erodibility

Twelve percent of samples had gully erosion and 27% had scalding erosion. The mean area affected by gullying was 1% and by scalding 9%. The mean number of gullies and the mean percent of scalding were greatest on the northern side of the valley where intensity of stock use was least. Russell Grant of the Conservation Commission Land Resources Unit assessed erodibility (erosion hazard) of soil by photo-interpretation and assigned greatest erodibility to the northern half of the valley. Within 5.5 km of the semi-permanent water-hole, soil erodibility appeared to influence erosion more than the intensity of stock use (Figure 8.5 & Figure 8.6).

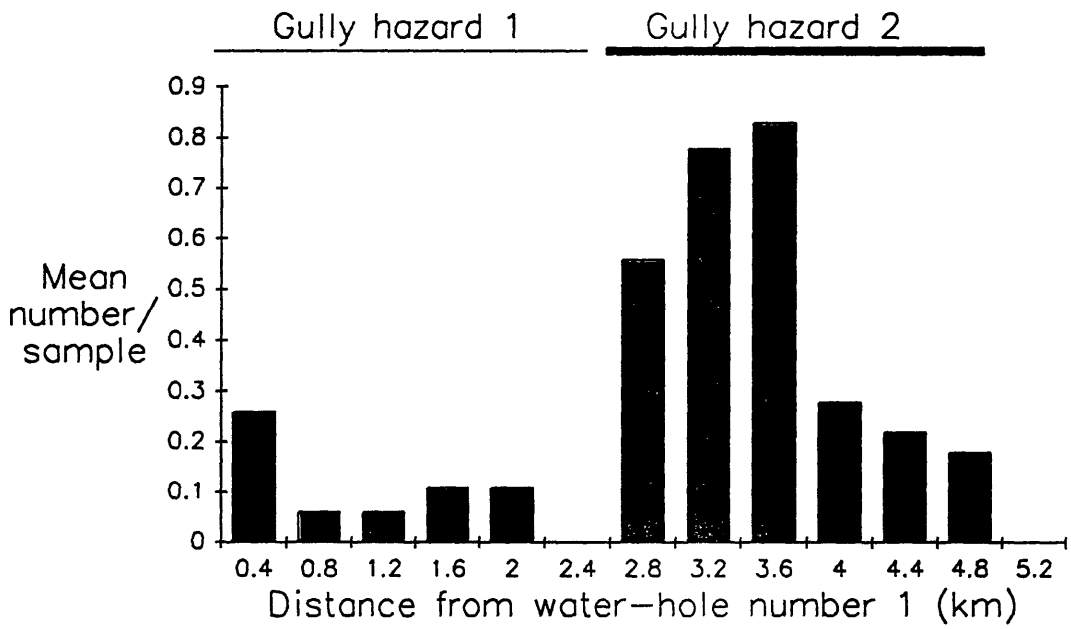

Figure 8.5: Mean number of gullies walked across per 100 m calculated for 400 m x 450 m sections of 10 transects (n=20) started at water-hole number 1 (19 Mile valley) (Hazard p.53).

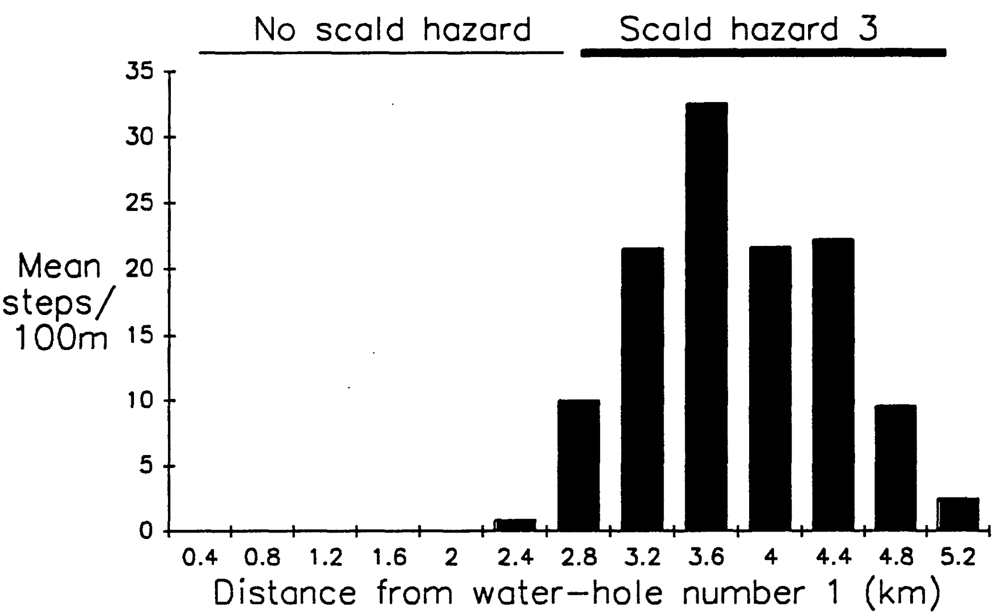

Figure 8.6: Mean percent steps on scald per 100 m calculated for 400 m x 450 m sections of the group of 10 transects (n=20) started at water-hole number 1 (19 Mile valley)(Hazard p.53).

b) Nineteen Mile valley (5 to 65 km from permanent water)

This section describes the results for Nineteen Mile valley which represents an area from 5 km to 65 km from permanent water with some semi-permanent water-holes (Figure 8.1). Table 8.1 shows the linear correlation coefficients (n=2087 sample areas) for variables relating to animal signs and distance from drinking water. Table 8.2 contains linear correlation coefficients for variables relating to soil, vegetation and distance from drinking water. The correlation coefficients (r) and level of statistical significance (P) are shown to indicate the direction (negative, neutral or positive) and relative strength of relationships. Means were calculated for each of the 13 runs (groups of 10 transects) across Nineteen Mile valley (the number of sample areas n ranged from 91 to 222 per run) and plotted against distance from permanent water (Figure 8.7 to Figure 8.10).

Table 8.1: Linear correlation matrix for variables relating to distance from water, and animal signs, showing correlation coefficients and level of significance. Variables are defined in Chapter 2.

a) 19 Mile Valley (N=2087).

	Dist. near.	Stock Pads	Horse Dung	Cattle Dung	Dung Piles	Camel Dung	Rabbit Dung	Macro Dung~	Horse Tracks	Cattle Tracks	Camel Tracks	Other Tracks
DISTANCE FROM												
Perm. water	0.70**	-0.14**	-0.26**	-0.38**	0.04	0.19	0.53**	0.28**	-0.01	-0.32**	0.08*	0.29**
Nearest water	-	-0.19**	-0.25**	-0.23**	-0.04	0.23**	0.54**	0.32**	-0.06*	-0.24**	0.02	0.19**
ANIMAL SIGNS												
Stock Pads	-	-	0.19**	0.13**	0.06*	-0.03	-0.09*	-0.07*	0.07*	0.08*	0.00	-0.10**
Horse dung	-	-	-	0.30**	0.06*	-0.00	-0.09*	-0.04	0.19**	0.09*	-0.05	-0.09*
Cattle dung	-	-	-	-	0.08*	-0.03	-0.19**	-0.07*	0.07*	0.30**	-0.05	-0.10**
Dung piles!	-	-	-	-	-	-0.03	-0.01	-0.02	0.02	0.01	0.01	-0.00
Camel dung^	-	-	-	-	-	-	0.16**	0.14**	0.01	-0.03	0.17**	0.07*
Rabbit dung^	-	-	-	-	-	-	-	0.27**	0.05	-0.21**	0.02	0.22**
Macro.~ dung^	-	-	-	-	-	-	-	-	0.05	-0.14**	-0.02	0.16**
Horse tracks^	-	-	-	-	-	-	-	-	-	0.09*	0.02	0.01
Cattle tracks^	-	-	-	-	-	-	-	-	-	-	0.07*	-0.10**
Camel tracks^	-	-	-	-	-	-	-	-	-	-	-	0.02

b) Dry Creek valley (N=1085)

	Dist. near.	Stock Pads	Horse Dung	Cattle Dung	Dung Piles	Camel Dung	Rabbit Dung	Macro Dung~	Horse Tracks	Cattle Tracks	Camel Tracks	Other Tracks
DISTANCE FROM												
Perm. water	0.42**	-0.17**	-0.34**	-0.05	-0.13**	0.07*	0.04	0.24**	-0.21**	-0.08**	-0.04	0.08
Nearest water	-	-0.18**	-0.15**	-0.07*	-0.17**	-0.05	0.02	-0.16**	-0.15**	0.03	-0.12**	0.01
ANIMAL SIGNS												
Stock Pads	-	-	0.22**	0.05	0.27**	0.10**	0.00	-0.10**	0.28**	-0.00	0.07*	0.01
Horse dung	-	-	-	0.10**	0.32**	0.14**	-0.01	-0.12**	0.36**	0.17**	0.06	0.04
Cattle dung	-	-	-	-	0.06*	0.08*	-0.01	0.04	0.08*	0.02	0.04	-0.01
Dung piles!	-	-	-	-	-	0.10**	-0.03	-0.02	0.20**	-0.00	0.08*	0.08
Camel dung^	-	-	-	-	-	-	0.06*	0.15**	0.18**	0.09*	0.17**	0.27**
Rabbit dung^	-	-	-	-	-	-	-	0.09*	-0.00	0.08*	0.11**	0.08*
Macro.~ dung^	-	-	-	-	-	-	-	-	-0.06	-0.08*	-0.03	0.18**
Horse tracks^	-	-	-	-	-	-	-	-	-	0.07*	0.09*	0.17**
Cattle tracks^	-	-	-	-	-	-	-	-	-	-	0.11**	0.12**
Camel tracks ^	-	-	-	-	-	-	-	-	-	-	-	0.14**

* $p<0.05$
** $p<0.001$
^Non-continuous variables. Results to be treated with caution.
!Horse dung piles
~Macropods were Red Kangaroos or Euros
Dist. near. is distance from the nearest watering point of any type.
Perm. water is distance from a permanent watering point.

Table 8.2: Linear correlation matrix for variables relating to distance from water, soil, erosion and vegetation, showing correlation coefficients and level of significance. Variables are defined in Chapter 2.

a) 19 Mile Valley (N=2085)

	SECTION (100 steps)				SAMPLE AREA (15 m radius)							
	Dist. near.	Gullies No.	Steps	Scald	Soil depth	Slope	Soilsize	Gully steps	Scald %	Herb cover	Number of Trees	Shrubs
DISTANCE FROM												
Perm. water	-0.04	-0.22**	-0.08*	-0.02	-0.11**	-0.25**	-0.30**	-0.21**	0.10**	0.10**	-0.09*	0.37**
Nearest water	-	-0.02	-0.16**	-0.04	-0.11**	-0.02	-0.24**	-0.15**	-0.15**	-0.04	-0.05	-0.10**
SECTION (100 steps)												
Gully number	-	-	0.08*	-0.05	0.20**	0.01	-0.02	-0.07*	-0.08*	-0.05	0.17**	-0.10**
Gully steps	-	-	-	0.03	-0.04	0.26**	0.03	0.02	-0.05	-0.07*	-0.03	0.07*
Scalding	-	-	-	-	0.00	-0.06*	0.08*	-0.01	0.32**	-0.08*	-0.11**	0.03
SAMPLE AREA (15 m radius)												
Soil depth	-	-	-	-	-	0.04	-0.07*	0.19**	-0.04	0.04	-0.11**	-0.07*
Slope	-	-	-	-	-	-	0.04	-0.03	0.04	-0.12**	-0.04	-0.15**
Soil size	-	-	-	-	-	-	-	0.09*	-0.06*	-0.01	-0.04	-0.10**
Gully steps	-	-	-	-	-	-	-	-	0.05	-0.08*	0.16**	-0.06*
Scald %	-	-	-	-	-	-	-	-	-	-0.03	-0.10**	0.06*
Herb cover	-	-	-	-	-	-	-	-	-	-	-0.02	-0.01
Trees	-	-	-	-	-	-	-	-	-	-	-	-0.02

b) Dry Creek Valley (N=1085).

	SECTION (100 steps)			SAMPLE AREA (15 m radius)								
	Dist. near.	Gullies No.	Steps	Scald	Soil depth	Slope	Soilsize	Gully steps	Scald %	Herb cover	Number of Trees	Shrubs
DISTANCE FROM												
Perm. water	0.42**	-0.16**	-0.13**	-0.18**	-0.03	-0.08*	-0.05	-0.13**	-0.19**	0.17**	0.01	-0.06
Nearest water	-	0.02	-0.04	0.12**	-0.03	-0.10**	-0.06*	0.03	0.12**	-0.08*	-0.19**	0.04
SECTION												
Gully number	-	-	0.58**	0.18**	0.10*	-0.17**	-0.17**	0.38**	0.18**	-0.01	-0.06	0.04
Gully steps	-	-	-	0.11**	0.14**	-0.11**	-0.14**	0.44	0.14**	0.03	-0.01	0.02
Scalding	-	-	-	-	-0.01	-0.23**	-0.22**	0.10**	0.75**	-0.08*	-0.13**	-0.03
CIRCLE												
Soil depth	-	-	-	-	-	-0.16**	-0.24**	0.13**	-0.04	0.08*	0.07*	0.02
Slope	-	-	-	-	-	-	0.67**	-0.08*	-0.23**	-0.10**	0.13**	0.06*
Soil size	-	-	-	-	-	-	-	-0.13**	-0.20**	-0.12**	0.11**	0.03
Gully steps	-	-	-	-	-	-	-	-	0.09*	0.08*	0.01	0.03
Scald %	-	-	-	-	-	-	-	-	-	-0.10**	-0.15**	-0.06*
Herb cover	-	-	-	-	-	-	-	-	-	-	0.16**	0.00
Trees	-	-	-	-	-	-	-	-	-	-	-	0.06*

* $p<0.05$
** $p<0.01$

Note: Slope and Soil particle size are non-continuous variables and therefore correlation results with respect to these variables must be treated with caution.
Dist. near is distance from the nearest watering point of any type.
Perm. water is distance from a permanent watering point.

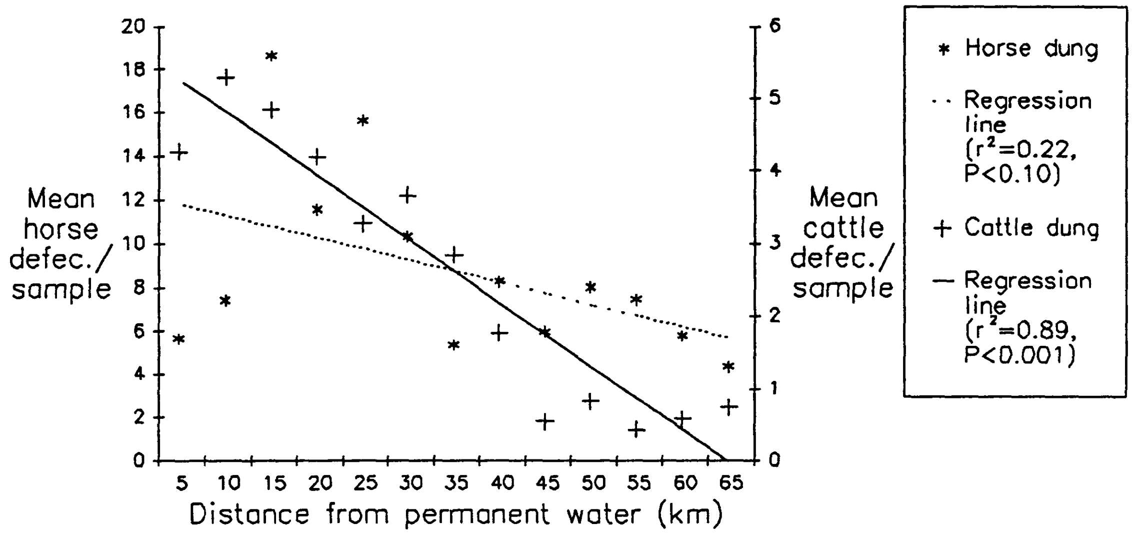

Figure 8.7: Mean number of horse and cattle defecations per sample area plotted against distance from permanent water in 19 Mile valley from 5 to 65 km from Piperie Spring (Figure 8.1).

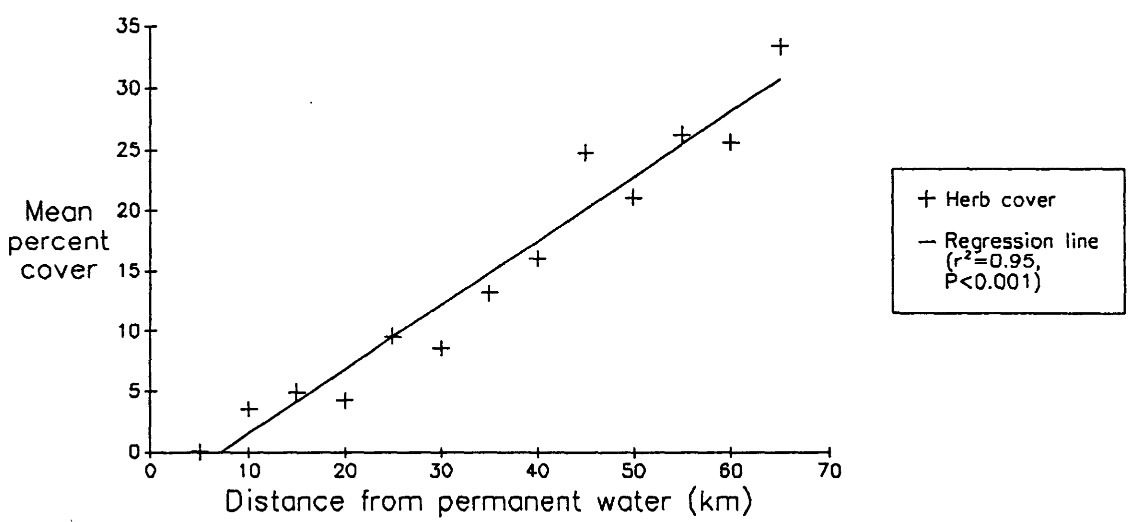

Figure 8.8: Relationship between mean herb cover and distance from permanent water in 19 Mile valley (5 to 65 km from permanent water). Number of sample areas per run (n) ranged from 91 to 222.

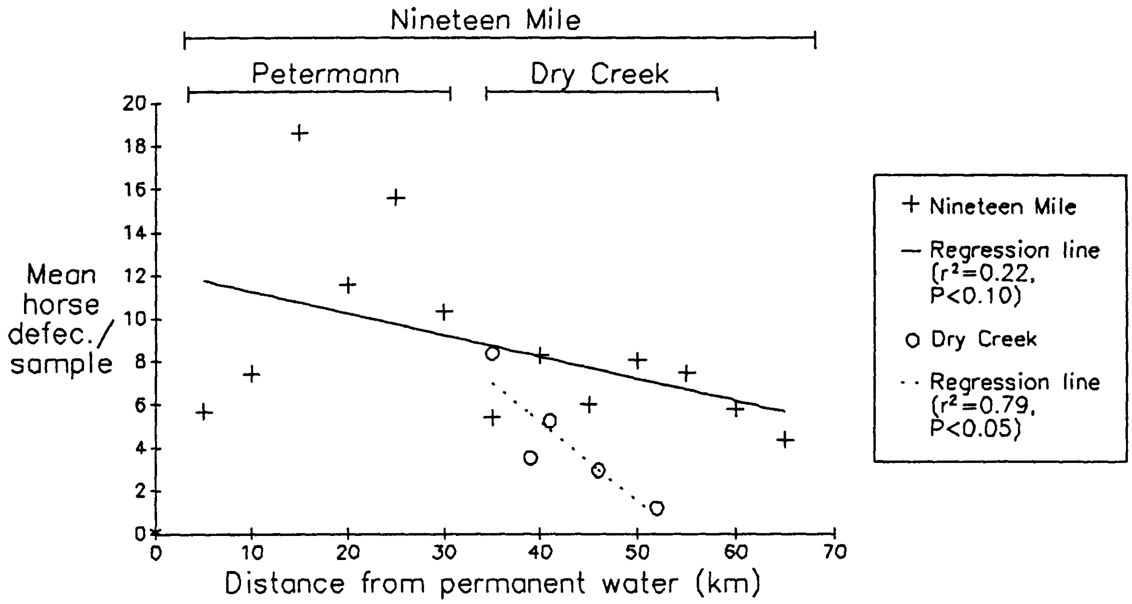

Figure 8.9: Comparison of Dry Creek and Nineteen Mile valleys. Relationship between mean number of horse defecations and distance from permanent water. (n ranged from 91 to 305 sample areas). Petermann valley was not surveyed.

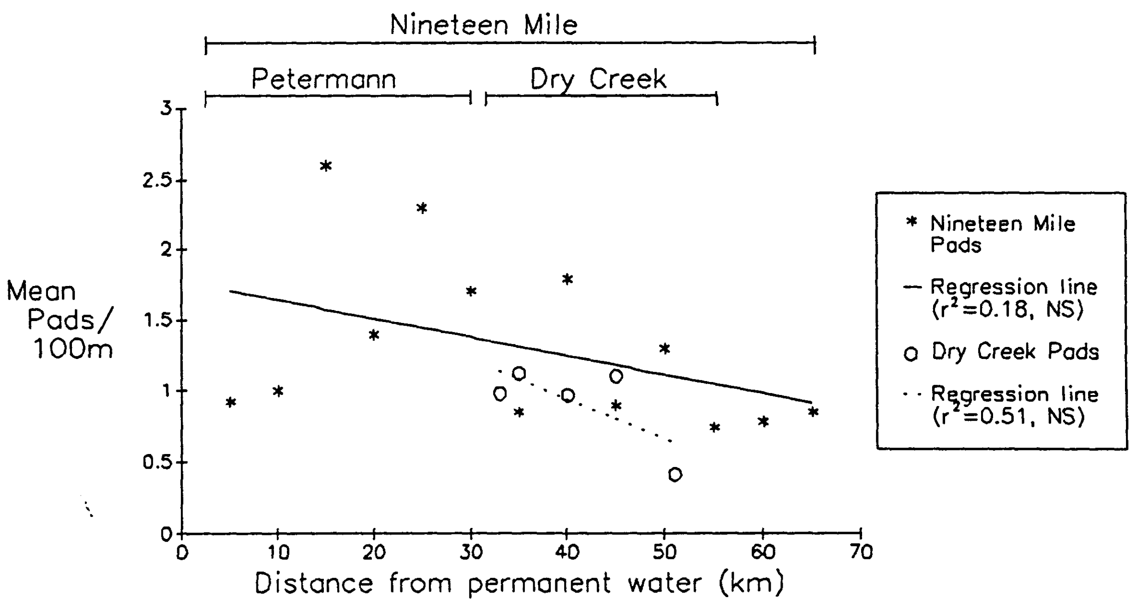

Figure 8.10: Comparison of Dry Creek and Nineteen Mile valleys. Relationship between mean number of stock pads (trails) and distance from permanent water (n=91 to 305 sample areas per run). Petermann valley was not surveyed.

Table 8.3: Proportion of a) all and b) flat samples, where the signs of stock (dung, tracks and pads) were recorded.

a) ALL SAMPLES		
Variable	Nineteen Mile Percent (n=2087)	Dry Creek Percent (n=1085)
Horse dung	94%	68%
Horse tracks	90%	70%
Cattle dung	53%	3%
Cattle tracks	23%	2%
Stock pads	56%	44%
b) FLAT SAMPLES (slope<2 degrees)		
Variable	Nineteen Mile Percent (n=1792)	Dry Creek Percent (n=564)
Horse dung	96%	79%
Horse tracks	91%	85%
Cattle dung	54%	5%
Cattle tracks	23%	3%
Stock pads	57%	53%

i) Horse and cattle distribution

Table 8.3 shows the proportion of sample areas for which dung, tracks and pads (stock trails) were recorded. The dung, tracks (hoof prints) and pads (trails) of horses and cattle tended to decrease in abundance as distance from permanent water increased in Nineteen Mile valley. Statistically significant linear correlations (Table 8.1) between the number of defecations of both horses ($P<0.001$, $r=-0.26$) and cattle ($P<0.001$, $r=-0.38$), and distance from permanent water were calculated (n=2087). Table 8.1 shows significant negative linear correlation coefficients calculated for distance from permanent water and stock pads (trails), horse dung, cattle dung, and cattle tracks (hoof prints). Stock pads are trails created and used by both horses and cattle. The presence or absence of horse tracks (hoof prints) in sample areas was the only horse or cattle variable not significantly related to distance from permanent water.

Figure 8.7 illustrates the relationship between mean number of defecations per sample for horses and cattle for 13 runs across Nineteen Mile valley. They were negatively correlated with distance from permanent water (Piperie Spring). The linear relationship between mean number of cattle defecations and distance from permanent water was statistically significant but that for horse defecations was not significant (Figure 8.7).

ii) Vegetation

Percent herb cover was positively correlated (n=2087) with distance from permanent water (Piperie Spring) ($P<0.001$, $r=0.10$) (Table 8.2). The number of shrubs increased ($P<0.001$, $r=0.37$) and the number of trees decreased ($P<0.01$, $r=-0.09$) with increasing distance from permanent water.

iii) Soil, slope, erosion and erodibility

Table 8.4 shows proportions of samples with gullies and proportion with scalding erosion for both valleys. Results of linear correlation analyses appear in Table 8.2. There tended to be more gullies ($P<0.001$, $r=-0.22$) and the greatest proportion of land subjected to gully erosion ($P<0.05$, $r=-0.08$) in areas close to permanent water than further away (n=2087). The number of steps that were on scalded areas in 100 steps was not significantly correlated with distance from permanent water ($P>0.05$, $r=-0.02$) but estimates of the percent of area scalded in each sample were positively correlated with distance from permanent water ($P<0.001$, $r=0.10$). Most scalding erosion occurred in an area from 30 to 60 km from permanent water where the soil type (duplex soil having developed in situ possibly on calcareous siltstone or mudstone) is most prone to scalding erosion.

Soil penetrability (measured by the depth that a steel probe could be pushed into the soil), slope (steepest recorded within circular sample), and the size of the dominant soil

Table 8.4: Percentage of area with erosion and area with erosion hazard for 13 runs across Nineteen Mile valley. Correlation coefficients for linear regressions of arcsine transformed data are shown.

Distance from permanent water	Hazard		Erosion	
	Gully	Scald	Gully	Scald
5	17	0	100	83
10	100	100	100	100
15	100	0	50	75
20	100	0	50	83
25	100	0	50	50
30	71	14	86	100
35	75	12	100	75
40	85	38	85	77
45	92	25	75	92
50	70	0	60	90
55	67	44	44	100
60	62	50	38	100
65	30	30	40	90

Correlation coefficients for regressions	Hazard		Erosion	
	Gully	Scald	Gully	Scald
Distance water	-0.39	0.18	-0.57*	0.30
Gully hazard	-	-	-0.11	-
Scald hazard	-	-	-	0.66*

* P<0.05, n=13 runs (i.e. groups of 10 transects)

particle all correlated negatively with distance from permanent water. Determining causal relationships between these variables, gully erosion and intensity of stock use is therefore difficult.

Soil penetrability was positively correlated with the number of gullies ($P<0.01$, $r=0.20$) and the number of steps taken in gullies while walking around the circumferences of sample areas ($P<0.01$, $r=0.19$). Gullies appear to be usually in areas where the soil is softest, and probably alluvial. The bottom of the largest gullies and major water-courses were often covered with gravel or coarse sand. Hence, the size of the dominant soil particle was positively correlated with the number of steps, walked around the circumference of sample areas which fell in gullies ($P<0.05$, $r=0.09$).

The size of the dominant soil particle was negatively correlated with scalding percent per sample area ($P<0.05$, $r=-0.06$). Samples occurring on large areas of scald were less likely to have within them the sandy loam A-horizon and more likely to have areas of exposed clay B-horizon. The number of steps on scald while walking between circular sample areas was positively correlated with the size of soil particles. This suggests that if you have just walked across a large area of exposed clay B-horizon (scald) while stepping between sample areas, your circular sample area is less likely to contain a large area of scald and more likely to encompass an area of sandy loam A-horizon.

Scalded areas were generally flat to gently sloping surfaces. The number of steps on scalded areas while walking between circles was negatively correlated with the slope within circular sample areas ($P<0.05$, $r=-0.06$). Nineteen Mile valley was predominantly flat to gently sloping (86% of samples with slope<2 degrees). Most of the recorded steep slopes were probably sides of the deeper water-courses or gullies and may not reflect the general landform. Hence, the number of steps in gullies was positively correlated with slope ($P<0.01$, $r=0.26$).

Table 8.5 shows the proportion of samples with "highest erodibility" based on slope (slope>2 degrees), texture (soil size score=0, clay) and soil penetrability (penetrability>2 cm). The regression of "high erodibility" on the area affected by gullying was positive (NS, $r=0.42$, $n=12$ runs). "High erodibility" was also positively correlated with scalding ($P<0.05$, $r=0.59$, $n=12$ runs). A multiple linear regression indicated the mean steps in gullies per sample can be predicted by distance from water (which explains 31% of the variation in gullies) and percent of samples with "high erodibility" (explains 21%) ($P<0.05$, $r2=0.38$) (Table 8.5).

The percentage of area with erosion hazard (classification based on photo-interpretation) for each run (group of 10 transects) across Nineteen Mile valley was

Table 8.5: "High erodibility" based on slope (slope>2 degrees), texture (soil size score=0, clay) and soil penetrability (penetrability>2 cm) and the mean percent of area affected by gully and scald in Nineteen Mile valley.

Distance from permanent water	% samples with "high erodibility"	Erosion mean steps/sample	
		Gully	Scald
5	2	5	4
10	5	10	2
15	3	3	0
20	1	0	1
25	1	0	1
30	2	1	5
35	4	2	8
40	5	1	9
45	6	2	12
50	3	1	5
55	3	2	8
60	1	1	6
65	14^	1	1

Correlation coefficients		Erosion	
	"Erodibility"	Gully	Scald
Distance from water	0.07	-0.53	0.66*
Gully erosion	0.42	-	-0.19
Scald erosion	0.59*	-	-

Results of multiple linear regression to predict gullying		
$y= 2.9 + 0.8a - 0.09b$ ($P<0.05$, $r^2=0.49$) where y is the mean area affected by gullying, a is the area with "high erodibility" and b is distance from permanent water		
	a	b
Partial correlation	0.54	-0.62
Contribution r^2	0.21	0.31

^ Fine dune sand was wrongly classified by venturers as silt or clay. Sand dunes are not susceptible to gully or scald erosion so these data were excluded from regressions
*P<0.05

transformed using arcsine for regressions (Table 8.4). Arcsine percent of area with gully erosion was significantly, negatively correlated with distance from permanent water ($P<0.05$, $r=-0.57$, $n=13$), but percent of area with scald erosion was not.

Arcsine percent of area with scald erosion hazard was positively correlated with arcsine percent of area with scald erosion ($P<0.05$, $r=0.66$, $n=13$). However, arcsine percent gully erosion hazard was not significantly correlated with arcsine percent area with gully erosion.

There were significant negative correlations between distance from water and gully erosion for areas where gully hazard=0 and gully hazard=1 but not where gully hazard=2 (Table 8.6).

iv) Native wildlife

The presence of macropod dung in sample areas was positively correlated with distance from permanent water ($P<0.001$, $r=0.28$, $n=2085$), negatively correlated with number of cattle defecations ($P<0.05$, $r=-0.07$) and cattle tracks ($P<0.001$, $r=-0.14$) and was not significantly related to horse dung or tracks. Other (i.e. neither horse nor cattle) tracks were identified if possible and were mostly macropod tracks but also included rabbit tracks. The presence of other tracks in sample areas was positively correlated with distance from permanent water ($P<0.001$, $r=0.29$), presence of macropod dung ($P<0.001$, $r=0.16$) and rabbit dung ($P<0.001$, $r=0.22$) in sample areas. Stock pads (trails), horse and cattle defecations, and cattle tracks all correlated negatively with other tracks, which were mostly macropod tracks (Table 8.1).

c) Dry Creek/Petermann (35 to 55 km from permanent water)

This section describes the results of analyses of data collected in the Dry Creek valley as well as comparisons with results from data collected in Nineteen Mile valley. Table 8.1 shows the linear correlation coefficients for variables relating to animal signs and distance from water. Table 8.2 contains linear correlation coefficients for variables

Table 8.6: Correlation coefficients for linear regression of erosion (steps in gullies and scald) and distance from permanent water in Nineteen Mile valley.

Erosion hazard	n	Gully	Scald
Gully hazard=0	28	-0.39*	-0.10
Gully hazard=1	53	-0.28*	0.14
Gully hazard=2	18	0.14	0.28
Gully hazard=3	5	all 10 km from permanent water	
Scald hazard=0	78	-0.25*	0.06
Scald hazard=1	7	-0.10	0.04
Scald hazard=2	7	-0.53	0.38
Scald hazard=3	12	0.19	0.21

relating to soil, vegetation and distance from drinking water. Means were calculated for each of the 5 runs (groups of 10 transects) across Dry Creek valley (n ranged from 137 to 305 sample areas) and plotted against distance from permanent water (Figure 8.9 and Figure 8.10).

The data referred to in this section are from an area 35 to 55 km from permanent water (Farrer Spring). We were unable to survey Petermann valley because there were mustering activities in the area at that time. Cattle sign data collected in Dry Creek valley are considered unreliable because of low frequency of occurrence (Table 8.7).

i) Horse and cattle distribution

In Dry Creek valley we obtained similar results to those of Nineteen Mile valley for dung, tracks (hoof prints) and pads (trails) of horses (Table 8.1 and 8.2). Horse signs tended to decrease in abundance as distance from permanent water increased. Statistically significant linear correlations (Table 8.1b) between horse defecations and distance from permanent water were calculated ($P<0.001$, $r=-0.34$, cf. 19-Mile $r=-0.26$). Table 8.1b shows significant negative linear correlation coefficients calculated for distance from permanent water and all variables relating to horses signs. The relationship between distance from permanent water and the presence or absence of horse tracks (hoof prints) in sample areas was significant for Dry Creek but not Nineteen Mile valley data. A difference between valleys was also recorded for horse dung piles (Table 8.1).

Figure 8.9 illustrates the relationship between mean number of defecations per sample for horses for 5 runs across Dry Creek valley. The linear relationship between mean number of horse defecations and distance from permanent water was statistically significant ($P<0.05$, $r=-0.89$).

ii) Vegetation

Percent herb cover (Table 8.1) was positively correlated with distance from permanent water (Farrer Spring) ($P<0.001$, $r=0.17$, cf. 19-Mile $r=0.10$) in Dry Creek valley. Neither the number of shrubs nor the number of trees was significantly related to distance from permanent water in Dry Creek valley, differing from the results of Nineteen Mile valley (shrubs $r=0.37$ and trees $r=-0.09$).

iii) Soil, erosion and erodibility

Results of linear correlation analyses appear in Table 8.2. There tended to be more

Table 8.7: Proportion of all samples a) and samples with "high gully erodibility" (slope>2 degrees, silt or clay, penetrability<2 cm) b) where gullies and scalding were recorded.

a) All samples	Nineteen Mile Percent (n=2087)	Dry Creek Percent (n=1085)
With gullies	13%	19%
With scalding	17%	15%
b) "Highly erodible" samples	Nineteen Mile Percent (n=153, 7%)	Dry Creek Percent (n=66, 6%)
With gullies	21%	26%
With scalding	12%	14%

gullies ($P<0.001$, $r=-0.16$) and the greatest proportion of land subjected to gully erosion ($P<0.001$, $r=-0.13$) in areas close to permanent water than in areas further away. Similar relationships were obtained for Nineteen Mile valley. Unlike Nineteen Mile valley, scalding was significantly correlated with distance from permanent water ($P<0.001$, $r=-0.18$). Estimates of the percent of area scalded in each sample were also negatively correlated with distance from permanent water ($P<0.001$, $r=-0.19$). Most scalding erosion occurred in the eastern end of Dry Creek valley where the soil type (duplex soil having developed in situ possibly on calcareous siltstone or mudstone) is most prone to scalding erosion and appears virtually the same as the soil of scalded areas in Nineteen Mile valley.

Soil penetrability and the size of the dominant soil particle were both correlated negatively with distance from permanent water but the relationships were not statistically significant ($P>0.05$), in contrast to those from Nineteen Mile valley. Slope was significantly correlated with distance from permanent water ($P<0.05$, $r=-0.08$) reflecting the fact that the hills are steeper in the eastern part of the valley than they are in the west.

Soil penetrability was positively correlated with the number of gullies ($P<0.05$, $r=0.10$, cf. 19-Mile $r=0.20$) and the number of steps in gullies around the circumference of sample areas ($P<0.01$, $r=0.14$; cf. 19-Mile $r=0.19$). As for Nineteen Mile valley, gullies appear to be in areas where the soil is softest, probably sandy, alluvial soils. Dry Creek valley has more stony hills and terraces than Nineteen Mile valley. Hence, the size of the dominant soil particle was positively correlated with slope and this relationship was highly significant ($P<0.001$, $r=0.67$). There were few gullies and no scalds on the stony hills and therefore the dominant soil particle size was negatively correlated with all variables concerning erosion (Table 8.2).

Scalded areas were generally flat to gently sloping surfaces. The number of steps on scalded areas while walking between circles was negatively correlated with the slope within circular sample areas ($P<0.001$, $r=-0.23$, cf. 19-Mile $r=-0.06$). In Nineteen Mile valley most of the recorded steep slopes were probably sides of the deeper water-courses or gullies and may not reflect the general landform, whereas in Dry Creek valley the slope data reflect well the landforms. Hence, the number of steps in gullies was positively correlated with slope in Nineteen Mile ($P<0.01$, $r=0.26$) and negatively correlated in Dry Creek valley ($P<0.01$, $r=-0.11$).

iv) Native wildlife

The presence of macropod dung in sample areas was positively correlated with distance from permanent water ($P<0.001$, $r=0.24$, $n=1085$; 19-Mile $r=0.28$), negatively correlated with number of horse defecations ($P<0.001$, $r=-0.12$; 19-Mile NS $r=-0.04$) and stock pads ($P<0.001$, $r=-0.10$; 19-Mile $r=-0.07$). Figure 8.11 shows the positive relationships between distance from permanent water and macropod dung in both Nineteen Mile and Dry Creek valleys.

As for Nineteen Mile valley, the presence of macropod dung was positively correlated with the presence of camel dung and the presence of rabbit dung (Table 8.1). Other tracks were mostly macropod tracks but also included rabbit tracks. The presence of other tracks in sample areas was positively correlated with distance from permanent

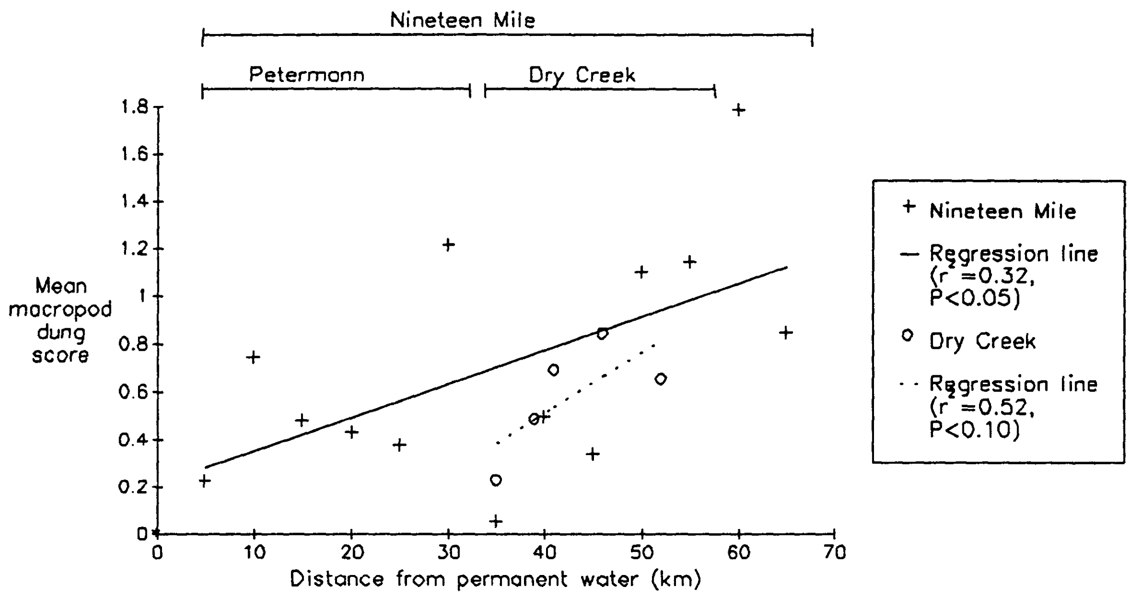

Figure 8.11: Comparison of Dry Creek and Nineteen Mile valleys. Relationship between mean macropod dung score and distance from permanent water (n=91 to 305 sample areas per run). Petermann valley was not surveyed.

water ($P<0.05$, $r=0.08$; 19-Mile $r=0.29$), presence of macropod dung ($P<0.001$, $r=0.18$; 19-Mile $r=0.16$) and rabbit dung ($P<0.001$, $r=0.08$; 19-Mile $r=0.22$) in sample areas. Macropods appear to avoid areas which are used heavily by horses, that is, areas relatively close to permanent water. Stock pads (trails), horse and cattle defecations did not correlate significantly with other tracks in Dry Creek valley, differing from the results for Nineteen Mile valley (Table 8.1).

8.3.3 Shrub damage

Results of shrub assessment indicated that mulga (*Acacia anura*) and prickly wattle (*Acacia victoriae*) were damaged more frequently than other trees or shrubs. *Cassia* spp. were least damaged by browsing. Most shrub damage occurred close to watering points in Nineteen Mile valley. There was very little shrub damage in Dry Creek valley.

8.3.4 Comparison of valleys

a) Distribution and abundance of horse and cattle signs

Horse dung and horse tracks were recorded in 94% and 90%, respectively, of samples searched in Nineteen Mile valley (n=2087) (Table 8.7). A smaller proportion of samples searched in Dry Creek valley had horse dung (68%) and horse tracks (70%) (n=1085) than was recorded for Nineteen Mile valley. Cattle signs were less abundant and widespread than horse signs in both valleys (Table 8.7). For Nineteen Mile valley 53% of samples had cattle dung present and 23% had cattle tracks. The few cattle signs recorded in Dry Creek valley (dung 3% and tracks 2% of samples) were probably of a small number of stray cattle that watered near Kings Canyon. Stock pads are trails created and used by both horses and cattle, and were more abundant in Nineteen Mile valley (56%) than Dry Creek valley (44%).

Nineteen Mile valley is generally flatter than Dry Creek valley. Eighty six percent of Nineteen Mile valley samples, and 52% of Dry Creek valley samples were classified as flat (slope<2 degrees). When all samples with slope greater than 2 degrees were excluded from calculations the abundance of horse signs recorded in Dry Creek valley was closer to but still less than that for Nineteen Mile valley (Table 8.7). The lack of drinking water in Dry Creek valley compared to Nineteen Mile valley and the fact that stock must climb a steep rocky ridge (the saddle) while walking to and from water appears to limit the abundance of dung and tracks in Dry Creek valley.

b) Erosion

Although both valleys have a similar proportion of "erodible" samples (Nineteen Mile 7% and Dry Creek 6%) Dry Creek has 6% more samples with gullies than Nineteen Mile valley. The area affected by scalding was less in Dry Creek valley (3%) than Nineteen Mile valley (6%) because Dry Creek has more hilly country. Where the slope was less than 2 degrees the proportion of area affected by scalding was 6% for both valleys. There was 2% of both valleys affected by gullying (Table 8.8).

Table 8.8: Mean percentages of steps in gully and scald erosion for all samples and flat samples in both Nineteen Mile and Dry Creek valleys.

	All samples			Flat samples		
	Gully	Scald	n	Gully	Scald	n
19 Mile	2	6	2087	1	6	1792
Dry Creek	2	3	1085	2	6	564

c) Macropods and other animals

Red kangaroo and euro dung were not differentiated during sampling. They were both recorded as macropod dung. Macropod dung was recorded for 48% and 62% of samples searched in Nineteen Mile and Dry Creek valleys, respectively. For flat (slope<2 degrees) samples only, the proportions were 49% and 56%, Nineteen Mile and Dry Creek valleys respectively.

The inexperienced venturers found it difficult to distinguish tracks other than horse, cattle and camel tracks so they simply recorded the presence or absence of other tracks. Other tracks were identified by biologists and the majority were macropod tracks (red kangaroo and euro). There were some rabbit tracks, and a very few dingo and reptile tracks. Twenty nine percent of samples in Nineteen Mile valley and 25% of samples in Dry Creek valley contained tracks other than those of horses, cattle or camels. For flat samples (slope<2 degrees), the results were similar to the overall result, 28% and 25% Nineteen Mile and Dry Creek respectively.

8.4 Discussion

8.4.1 Environmental impact

Environmental impact of feral horses can be defined as any change to the environment caused directly or indirectly by feral horses. Some examples of direct environmental impact of feral horses are:

1. horse tracks (hoof-prints): each time a horse puts a hoof on the ground it disturbs the soil, unless the soil is too hard or covered by rock,
2. horse pads (trails or paths) are caused by horses walking repeatedly along certain routes,
3. piles of dung,
4. damage to plants by trampling,
5. ground laid bare by grazing,
6. damage to shrubs by browsing,
7. water-holes depleted by drinking,
8. water-holes dirtied by playing, dying or defecating in water,
9. visual changes to the Australian bush by just being there; and
10. auditory changes to the Australian bush by whinnying, snorting, galloping or trotting.

The direct environmental impact of feral horses is easy to detect (e.g. dung or snorting) and quantify but difficult in some cases (e.g. pads and grass removal) to distinguish from changes caused by other introduced herbivores, especially cattle.

The indirect changes to soil, vegetation and wildlife caused by feral horses are hard to quantify and are considered most important by many people because they are perhaps permanent, have no cure and therefore must be prevented. Some examples of indirect impact caused by horses are:

1. acceleration of erosion by removal of vegetation and disturbance of the soil with hard hooves,
2. change to pasture species composition by selective grazing or differential plant response to grazing,
3. restriction of the distribution and/or cause of extinction of native animals by removal of their food or shelter, and
5. reduction in frequency or intensity of grass fires and therefore increased shrub growth by removal of grass.

It is difficult to quantify the indirect impact of horses because there are many other possible causes of these changes. Cattle and rabbits may cause accelerated erosion and change the species composition of pasture. Foxes and cats could restrict the range and cause extinctions of native animals. Less aboriginal activity may have reduced the frequency of fires allowing increased shrub growth. Furthermore the great variability in rainfall (time and place) and variability in responses of plants and soil types to the impact of european settlement confound those who study the impact of any one factor.

8.4.2 The degree of impact of feral horses

a) Direct impact

The results of this project describe well the distribution of direct environmental impact of feral horses and cattle for the valleys studied. The ground was almost bare up to 10 kilometres west of the permanent water (spring) in Nineteen Mile valley, a result of grazing by both horses and cattle which drink at the spring (see Figure 8.1). There were also many broken trees and shrubs apparently caused by cattle browsing and even the spinifex (which is a very tough, unpalatable grass) was grazed to the ground within 5 km of the spring.

As the distance from the spring increased we found a corresponding decrease in plant damage and signs of stock use. This trend continued along the valley, except for the section near semi-permanent water-holes (clay pan and rock holes; see Figure 8.1). These rock holes may hold water for up to a year and allow stock to use that part of the valley heavily. Within this area grazing and tree damage increased as distance from the water-holes decreased.

Twenty kilometres west of the rock holes we found an area which appeared to be almost too far from water for stock. In this area there was plenty of palatable ground vegetation (*Enneapogon* spp. and *Digitaria* spp.) and no damage to trees or shrubs.

In Dry Creek valley a similar pattern was found with bare ground in areas closest to permanent water and palatable pasture species abundant in the far west of the valley. The obvious difference between the valleys was in the amount of damage to trees or shrubs. Very few branches were broken in Dry Creek valley, probably because there are few cattle there. Dry Creek valley is protected from cattle because it is too far from water and has a high barrier ridge (saddle) which must be climbed by stock as they travel too and from water. Horses appear to climb the saddle relatively easily; however, the extent of their distribution with respect to permanent water appears limited in Dry Creek valley compared to that of Nineteen Mile valley (Figure 8.9).

Dung and track distribution and observation of horses grazing 50 km from water in the Dry Creek valley showed that they are capable of exerting impact over a very large area. Few pastures in central Australia are too far from water for horses to reach. However, Chapter 5 shows that horses and cattle use areas within 3 km of water if sufficient forage is available there. Horses move further from water and into hills when pasture becomes scarce close to water (Chapter 5). It is logical to expect that the higher the density of horses the quicker pasture will be removed and the more rapidly impact will spread out from water. Management of horses and cattle so that the grazing pressure is low enough not to deplete pasture close to permanent water may confine their impact to these areas. Protection of areas highly susceptible to soil erosion may be achieved by fencing to exclude stock from drinking at nearby water-holes.

b) Indirect impact

Areas close to water had less herb cover than those more distant because horses and cattle used these areas most intensely. Gully erosion also appeared to be greatest in the areas closest to permanent water, whereas erodibility (erosion hazard) of the soils did not appear to be related to distance from water. This supports the hypothesis that horses and cattle indirectly cause accelerated gully erosion. However, we must be careful when assuming a causal relationship between stock use intensity and amount of erosion. Results for a single run (group of 10 transects) which started close to water-hole number 1 in Nineteen Mile valley (Figure 8.1) show that in some areas the intensity of stock use has little influence on the amount of erosion.

Although Dry Creek valley is protected somewhat from horses and cattle the amount of erosion appears to be similar to that of Nineteen Mile valley (flat samples 1 to 2% gully and 6% scald). Estimates of area affected by gullying (1 to 2%) are comparable to other estimates for part of Victoria River Downs station (north west Northern Territory) (1.4%) (Wood et al., 1979) and the upper Victoria River catchment (1%) (Condon 1986). The percent flat areas of Nineteen Mile and Dry Creek valleys affected by scalding (6%) is greater than estimates for Victoria River Downs (0.9%) (Condon 1986). During Operation Raleigh we were able to record only gullying (included rilling) and scalding. Other forms of soil erosion such as wind and sheet erosion could not be measured and may be significant forms of land degradation in Nineteen Mile and Dry Creek valleys.

By removing the herb layer both horses and cattle appear to influence the wildlife; for example, fewer kangaroo signs were seen in areas heavily grazed by stock

(Figure 8.11). Other wildlife species are undoubtedly influenced by grazing of horses and cattle but the degree of impact is difficult to determine.

c) Differences in impact of horses and cattle

Both horses and cattle have a marked impact on the herbaceous vegetation, create pads (trails), perhaps cause accelerated erosion, and influence macropod distribution. Cattle, but not horses, damage trees and shrubs by breaking branches and browsing on leaves.

The influence of horses is exerted much further from water than that of cattle for two reasons. Firstly horses are more mobile than cattle, and secondly cattle are normally managed whereas horses are not. In most areas in dry times cattle are removed by pastoralists when forage becomes scarce before they are forced to use areas more than 8 km from water, whereas feral horses are not managed and are often forced during dry times to feed great distances from water, denuding large areas of land and eventually, if not saved by rain, dying of starvation in or around water-holes.

8.4.3 Environmental damage versus environmental impact

This study shows that horses cause considerable direct environmental impact in central Australia and suggests that they also cause significant indirect changes such as accelerated erosion and restriction of suitable habitat for large macropods. Whether these changes, the environmental impact of horses, are considered to be environmental damage (i.e. injury or harm) is a matter of opinion. Some people like horses better than the native plants or animals. Furthermore no-one knows whether all the changes are reversible, nor does anybody know what other indirect changes may occur in the future as a result of not acting to reduce impact now. Reduction in productivity of central Australian rangelands below viability is one possible long-term result of the impact of feral horses and there may be other unexpected long-term damage.

8.5 Conclusion

As a result of varying availability of drinking water, the density of stock and grazing pressure varies between valleys and within valleys. Results indicate that variation in vegetation, wildlife and soil erosion correspond with changes in grazing intensity. We can conclude that horses help denude large areas, force macropods from these areas, foul water-holes with carcasses and cause accelerated gully erosion. Feral horses have the potential to exert impact on almost all areas of pasture in central Australia because they are able to walk up to 50 km from water and traverse hills which are barriers to cattle. Management of horses and cattle so that the grazing pressure is low enough not to deplete pasture close to permanent water may confine their impact to these areas. Fencing off water-holes may protect susceptible areas from the impact of feral horses.

We have obtained a detailed snap-shot of the environmental situation which is impossible using conventional ground-based or remote survey techniques. Operation Raleigh provided us with the means to survey intensively in a short time the extremely large areas that horses and cattle use in central Australia. We now have a far better idea of sampling intensity and techniques required to resurvey the valleys efficiently in order to monitor changes over time. The data will be useful when combined with satellite and aerial data for modelling and testing of models describing the interactions between cattle, feral animals, vegetation and erosion. Such models are necessary for efficient management of central Australian rangelands.

Fencing horses out of National Parks and harvest/cull operations on pastoral land are necessary to reduce the impact of feral horses on the environment. Monitoring sites for changes in soil erosion, vegetation and wildlife, in conjunction with active management of horse distribution and abundance, is necessary to justify control operations and increase our knowledge of impact.